RAPID-TEST
RT-1M

Fast Multitone Audio Analyzer

User Manual

WE ARE SETTING STANDARDS

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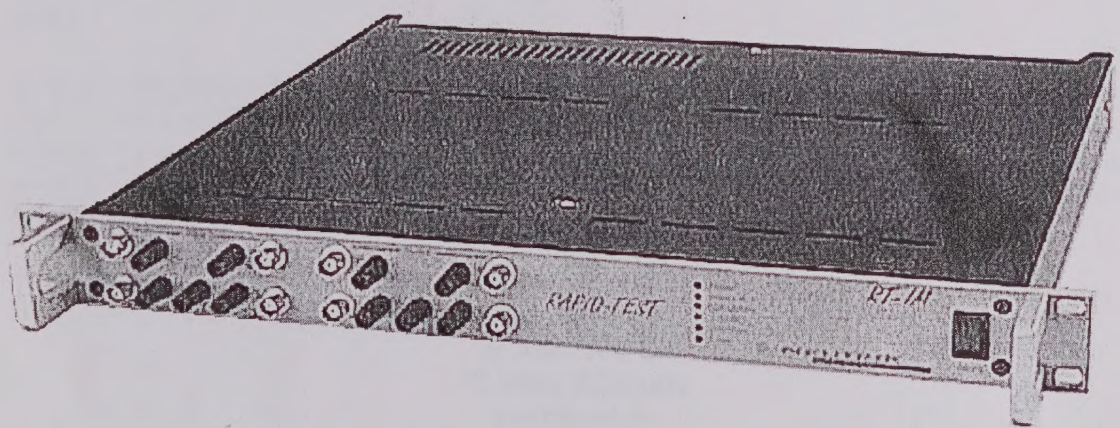
CONNECTING THE WORLD

User Manual

RT-1M



Multitone Audio Test System

Version 3.32 E
For Firmware Revision
3.25 and higher

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V 3.32 / Feb. 99
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INTERNATIONAL WARRANTY

Limited Warranty

NEUTRIK guarantees the *RT-1M* system and its components against defects in material or workmanship for a period of one year from the date of original purchase for use and agrees to repair or replace any defective unit at no cost for either parts or labor.

Important

This warranty does not cover damage resulting from accident, misuse or abuse, lack of reasonable care, the affixing of any attachment not provided with the product, loss of parts or connecting the product to any but the specified receptacles. This warranty is void unless service or repairs are performed by an authorized service center.
No responsibility is taken for any special, incidental, or consequential damages. In case of damage please take or ship prepaid your *RT-1M* System to your nearest authorized service center. Be sure to include your sales invoice as proof of purchase date. All transit damages that may eventually occur are not covered by this warranty.

Note

No other warranty, written or oral, is authorized by NEUTRIK. Except as otherwise stated in this warranty NEUTRIK makes no representation or warranty of any kind, expressed or implied in law or in fact, including, without limitation, implied merchantability or fitness for any particular purpose and assumes no liability, either in tort, strict liability, contract or warranty for products.

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WARNING! **Read this manual and especially chapter *2 INSTALLATION* carefully before operating the instrument. Important information about mains voltage selection and fuse rating are given there.**
Do never open, modify or try to repair this instrument unless properly instructed by an authorized service technician or NEUTRIK.

CE DECLARATION OF CONFORMITY

We, the manufacturer

NEUTRIK CORTEX Instruments AG
Im Alten Riet 34
FL-9494 Schaan

hereby declare that the product

Product Name	Rapid-Test
Model Number	RT-1M
Serial No.	
Year of Construction	1996

conforms to the following standards or other normative documents

EC-Rules	89/392, 91/368, 93/44, 93/68, 73/23, 89/336, 92/31
Harmonized Standards	IEC 65, IEC 68-2-31, IEC 348 EN50081-1, EN50082-1, EN50140, EN 61010-1

This declaration becomes void in case of any changes on the product without written authorization by NEUTRIK.

Date	Schaan, 12. August 1996
Signature	M. Becker
Position of Signatory	Product Manager Test Instruments

CE

Samples of this instrument have been tested and found to conform with the statutory protective requirements. Instruments of this type thus meet all requirements to be given the CE mark.

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1 OVERVIEW

The trend in modern audio testing is to reduce more and more the time required for a complete performance test of the device being tested. This tendency results partly from the demand of broadcasters being forced to provide 24hour programming, leaving little time for testing. In a modern studio with dozens of input channels, several routing paths and more than 24 recording channels, a complete test including all parts of the studio becomes very time-consuming and boring since the tests are highly repetitive.
Industrial applications also require reduced test time, especially at production lines where any time wasting process becomes a bottleneck. Reducing test time by a factor of 20 to 50 ensures for years that testing will not be the limiting factor and increases production density.

RT-1M is a modern and advanced audio test system with the capability to evaluate the important performance Parameter of a device within a fraction of a second. RT-1M is a complete, optimized system, containing a remote controllable generator as well as an intelligent analyzer, and can be easily integrated into an automated environment. The system provides the highest performance and specifications to meet also the requirement of professional equipment.

- *Frequency range* 20Hz to 20kHz
- *Output level* -60dBVp to +20dBVp
- *Input range* -60dBVp to +20dBVp
- *Measurements* level, noise, distortion, crosstalk and phase in one step
- *Burst transmission time* typ. 250-960ms
- *Residual distortion* < -86dB

RT-1M is very simple in terms of connecting, handling and use within any automated environment, but highly complex in terms of the implemented structures and algorithms to perform the analysis in a extremely short period of time.

RT-1M is very compact, using the most advanced technology available on the market. Within its case of 19" width and height of one unit (1.75") only, it provides two generator channels and two independent analyzer channels. The analyzer and generator can be operated completely independently even though they are located in the same housing.

There is no external synchronization required to perform the analysis. Each transmitted multitone signal contains an information header allowing any listening analyzer to synchronize onto the signal.

Communication

Since RT-1M does not provide any control elements, it must be completely controlled by a host PC. Due to performance reasons, an IEEE-488 parallel interface has been integrated into the instrument. This allows to transmit any command independently of the actual generator and/or analyzer activities. The instruction to transmit a previously defined multitone signal can be issued from the PC at any time.

Consequently, the basic requirements for the host PC is a standard IEEE-488 interface board with installed software drivers. Detailed descriptions of the IEEE-488 connection and all commands are filed in chapters ***Mains Cable*** and ***Programming*** respectively.

Accessories & Options

Software Tools

Following software packages for *RT-1M* are available free of charge from your local NEUTRIK representative.

- RT-EVAL Evaluation Software
- LabView® Driver Library
- LabWindows® CVI Driver Library

Please notice, that for either of these tools a GPIB-interface board from National Instruments™ (type GPIB-PCMCIA or GPIB/TNT or GPIB-PCIIA [production year 1992 or later]) must be installed in your host controller.

Application Notes

The appendix of this User Manual comprises the documents

- Introduction to *RT-1M*
- Get Familiar with Writing Code for *RT-1M*
- Cellular Phone Testing
- Comparison of Conventional vs. Multitone Testing

Additional application notes on speaker testing, external signal analysis etc. will be released in future. Please contact you local NEUTRIK representative for further information.

DTMF Option

Optional PCB to be installed internally, allowing to monitor 1 channel on incoming DTMF (Double Tone Multiple Frequency) signals in parallel to the normal operation (see p. *34*).

Microphones & Phantom Power Supply

NEUTRIK provides two measuring microphones for industrial applications.

- 3382 ¼" measuring microphone
- 3384 ½" measuring microphone

To allow the use of these microphones with *RT-1M*, an optional Phantom power box is available to provide the necessary supply voltage through XLR connectors. The box is plugged to the input banana connectors and comes along with an AC mains adapter.

2 INSTALLATION

This chapter is intended as help for proper unpacking and installation of the RT-1M system. Please read it carefully to avoid wrong connections or inconveniences during operation of the instrument.

Unpacking

RT-1M has been carefully packed by NEUTRIK to avoid damages during transportation. Should the box show severe damages, please immediately check the instrument inside on external impacts. In case of any visible damage, please do not send the instrument back but contact your local dealer and / or the carrier to avoid loss of claims for replacement.

Rack Mount

RT-1M is designed to mount in a 19" Rack and occupies one unit of height or rack space (1.75") only. Please allow at least 2" additional depth at the rear side for all necessary connectors. Make sure there is enough air circulation around the unit for cooling purposes and please do not place RT-1M besides high temperature devices such as power amplifiers in order to avoid overheating.
The specified operating temperature ranges between 5° and 45°C (40-110F) while humidity must not exceed 90% R.H. non-condensing.

AC Power Connection

Before connecting the instrument via mains cable to the power source, make sure that the voltage selector label on the connector / fuse holder assembly of the RT-1M system matches the supply voltage of the local area. If the instrument is not compatible with the available power source, follow the next paragraph to change the voltage selector.

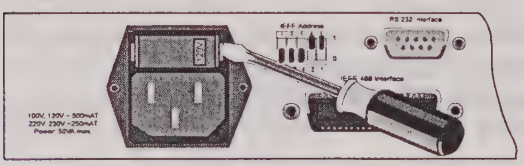


Fig. 1 Voltage Selector

RT-1M can operate from 100VAC, 120VAC and 230VAC sources. To reconfigure the input line voltage, remove the power cable and open the flap of the connector/fuse holder at the rear side of RT-1M. Either press a small screwdriver into the slot to open the flap as shown in ***Fig. 1*** or ruin your fingernails.

Take out the drum and insert it in the new position so that the matching voltage indication points towards you. At the same time replace the mains fuse with the proper current rating. For voltages of 100V to 120V a slow 2A fuse has to be installed, while for 230V a slow 1A fuse is appropriate.
After selection of the correct mains voltage and fuse, close the flap and insert the power cable.

RT-1M is designed with a protective ground (earth) connection through the ground wire of the power cord. This connection is essential for safe operation. Never operate the instrument if safety ground is unavailable or has been compromised.

Mains Cable

The enclosed mains power cable has an unconnected end with three colored leads, which correspond to

Brown	=	Live (AC)
Blue	=	Ground
Yellow/Green	=	Earth

Attach a mains plug to the cable that fits the receptacles of your country.

IEEE Connection

The *RT-1M* system provides an IEEE-488 interface (standard design interface for programmable instrumentation) which is connected to the IEEE bus using a standard IEEE-488 interface cable from the rear panel illustrated in ***Fig. 2***.

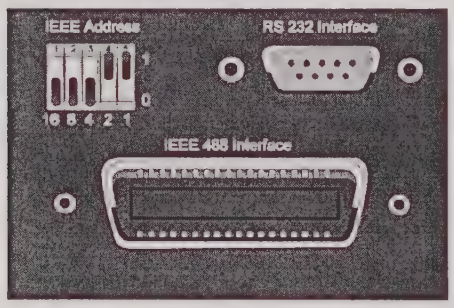


Fig. 2 IEEE Connector

With the IEEE interface bus, up to 31 instruments can be interconnected. The cables have identical piggy-back connectors on each end so that several cables can be connected in virtually any configuration. There must be, of course, a path from the computer to every device operating on the bus.

As a practical matter, avoid stacking of more than three or four cables to a single connector. If the stack gets too long, any force on the stack can damage the connector mounting. Be sure that each connector is firmly screwed in place.

IEEE Address Selection

Each IEEE device has at least one talk and listen address (unless totally transparent or a talk or listen only device). The address of the *RT-1M* can be adjusted with the DIP switch at the rear panel of the instrument (see ***Fig. 2***). Each switch position has a number printed underneath. The resulting IEEE address is the sum of all numbers, where the switch is in position "1". The above illustrated example has an address selection of 3, since switch 1 and switch 2 are in position "1". The five switches allow the selection of any address in the range from "1" to "31" inclusively.

Audio Connection

RT-1M features balanced and unbalanced BNC and 4mm banana connectors for both inputs and outputs. Balanced connections enhance the noise and hum immunity and are always recommended for measurement purposes. *RT-1M* can also handle unbalanced signals.

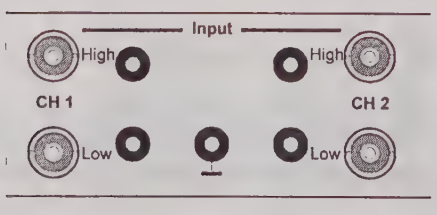


Fig. 3 Front Connectors

Unbalanced signals normally have one hot signal against chassis ground. For this reason unbalanced connections are recommended for short connections only (less than 1m / 3 feet) or in a relatively noise-free environment.

You may use either the set of front connectors with two inputs & outputs or the equivalent set of connectors at the rear panel of the instrument.

Caution: **Do not connect both front and rear panel connectors at the same time since this may result in signal mismatching.**

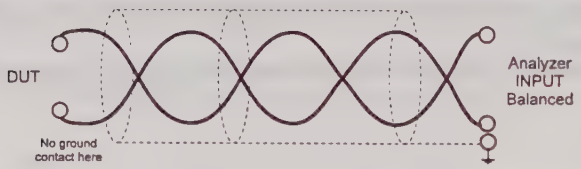


Fig. 4 Shielded Twisted Pair Cable

Connections between an unbalanced DUT and the balanced inputs of RT-1M should preferably be made with shielded twisted pair cables to avoid the introduction of noise and hum. The shield of such a cable shall be grounded only on one side. Grounding the shield on both sides increases the chance to build ground loops.

Balanced Connection

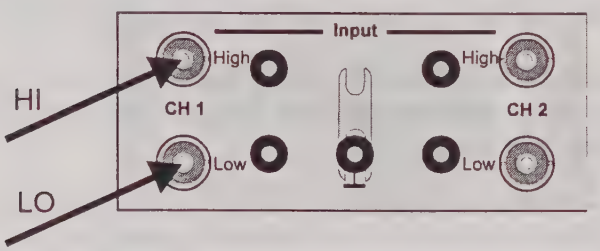


Fig. 5 Balanced BNC / Banana Connection

Fig. 6 BNC Cable - Balanced

Balanced connections with two BNC cables can be realized by connecting them to the RT-1M HIGH and LOW inputs. The ground shells of both connectors are wired to ground. Do not connect the shields together on the instrument side of the DUT but leave them open. With balanced connections do not assemble the short circuit bar.
You may also use banana inputs instead of BNC inputs. The respective HIGH and LOW inputs of the BNC and banana connectors are internally wired together.

Caution: **For balanced signals make sure that not only the front ground connection is disassembled but also the ground bar at the rear panel!**

Unbalanced Connection

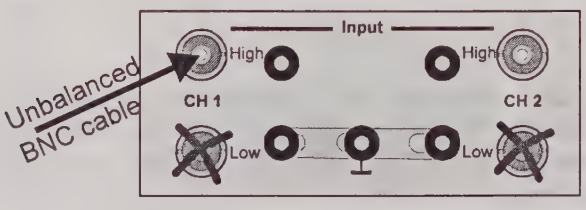


Fig. 7 Unbalanced Connection

If you use the HIGH input only of RT-1M for connecting the hot output of the DUT, use the BNC cable's shield as the return signal (common of the DUT output).
When using the generator in unbalanced mode, the available level will always be 6dB (50%) below the defined level.

Battery Low Indication

RT-1M contains a battery for backup purposes of the internal memories. Life expectancy of the battery is about ten years. Should the battery become low, the 'Error' LED will blink 3 to 4 four times after a start-up and ***Error 220 Battery low (memory backup)*** is generated.

LED Indicators

During the initialization period of RT-1M system (normally <1s) all LEDs are active. If the unit is switched ON for the very first time or after a firmware change, it has to initialize all its signals and tables. This might take up to a few minutes, depending on the signal resolution. All LEDs are lit during this period.

Power

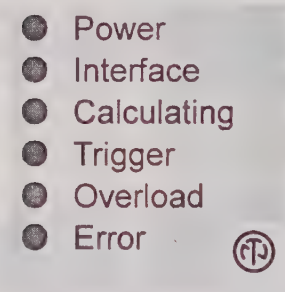


Fig. 8 LED Indicators

This LED indicates that the power of the system is switched on, the internal supply voltages are operating normally and the self-test of the system has been successfully completed.

Should it stay off after switching on the instrument please check whether the power cable is connected to the system, the voltage selector is set for the correct supply voltage and the wall socket is switched on.
Should the power LED still be off, check the power fuse in the connector / fuse holder assembly of RT-1M. Please refer to ***AC Power Connection*** to see how to open it.

WARNING Do not try to do further repairs. Call your local dealer for support.

Interface

This LED indicator lights up if the IEEE interface is busy and receives a command. It remains illuminated until the user has read the answer from the interface. In standby mode with no activity on the IEEE interface the LED is off.

Calculating

Whenever FFT or filtering calculations are performed this LED lights up.

Trigger

This LED indicator goes on as soon as a RT-1M trigger has been successfully detected and remains lit until the user has read the result(s) from the buffer.

Overload

Should the input signal overload one or both channels, the LED indicator goes on. This happens if the maximum input voltage of 20dBu (10V) is exceeded or if a higher voltage than the selected range is applied. In such a case the error LED also lights up. The overload LED resets with the next measurement and the ranges set correctly.

Error

RT-1M handles an error queue internally. Whenever an error is detected – hardware or software – the error LED comes on. It disappears as soon as the error number has been queried through the IEEE interface.

Test of Function

After connection of the cables and proper setting of the IEEE address it is recommended to run the subsequent short program to confirm the proper function of the system. *RT-1M* can be operated with any operating system providing an IEEE-488 interface.

HT-BASIC Program Example

```
 10                                      !    RT-1M Demo Program
 20
 30  Adr=11                              !    enter IEEE address here
 40
 50  Adr=Adr+700                         !    evaluate output/enter address J
 51  GOSUB 900                           !    read device informations
 60  OUTPUT Adr;"Output:Mtone:Active 1" END
 65  OUTPUT Adr;"Output:MTone:Start" END !    measurement loop
 70  OUTPUT Adr;"Measurement1:Level?" END !   terminate output with END
 80  GOSUB 1000                          !    read the measurements
 90  PRINT
100  GOTO 65
110  STOP
900                                      !    read system information
905  DIM Inf$[100]
910  OUTPUT Adr;"System:Information?" END
920  ENTER Adr;Inf$
930  PRINT Inf$
940  RETURN
1000                                     !    interpret incoming data stream
1010 DIM Rcv$[1000]
1020 DIM X$[10]
1030 DIM Y$[20]
1040
1050 ENTER Adr;Rcv$                      !    read data A
1060 Xpos=POS(Rcv$,"/")                  !    find X/Y separator
1070 Ypos=POS(Rcv$,",")                  !    find Y/X separator
1080
1090 WHILE (Xpos>0) AND (Ypos>0)         !    as long as there are separators do:
1100       X$=Rcv$[1,Xpos-1]             !    isolate X value
1110       X=VAL(X$)                     !    convert X string to value A
1120       Ypos=POS(Rcv$,",")            !    find Y/X separator
1130       IF Ypos>0 THEN                !    is there another value? >
1140             Y$=Rcv$[Xpos+1,Ypos-1]  !    isolate Y value
1150       ELSE
1160             Y$=Rcv$[Xpos+1,LEN(Rcv$)] !  isolate Y value
1170       END IF
1180       Y=VAL(Y$)                     !    convert Y string to value
1190       Rcv$=Rcv$[Ypos+1,LEN(Rcv$)]   !    delete the read XY pair from string
1200       Xpos=POS(Rcv$,"/")            !    find next X/Y separator
1210       PRINT "Bin# ",X,"Meas: ",Y
1220 END WHILE
1230 RETURN
1240 END
```

3 System Description

Multitone Signals

Traditionally, audio testing stimulates the device under test (DUT) with a sinusoidal signal. This type of signal is relatively easy to handle and distortion measurements may be performed by simply notching out the single frequency.

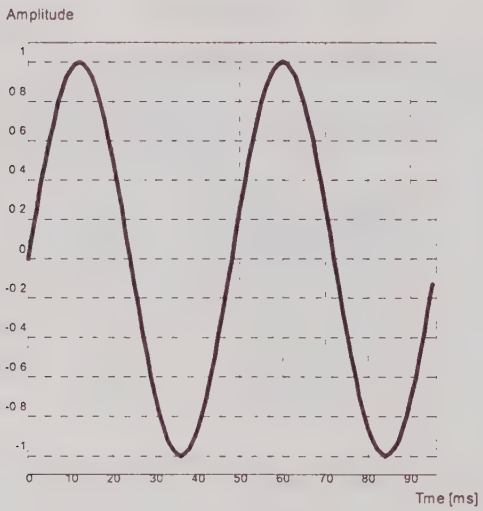


Fig. 9 Time Plot of Sinusoidal Signal

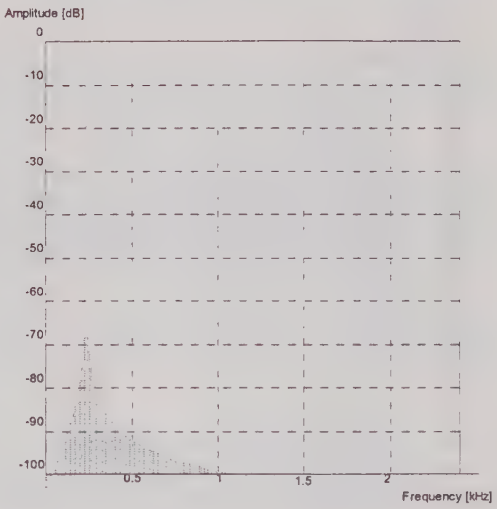


Fig. 10 Spectrum of Sinusoidal Signal

More advanced tests like intermodulation distortion measurements stimulate the device with a pair of sinusoidal signals to come closer to the real situation of audio signal transmission. In the presence of nonlinear transfer characteristics, the DUT generates new harmonic and intermodulation frequencies.

However, in practice the device is normally stimulated by music or speech which is a far more complex signal than any single or twin tone test. Many frequencies with non-correlated phase relations exist in such a real-world signal.

Therefore, multitone testing is a much more realistic approach for audio testing, emulating the complex structure of natural sound. A multitone signal typically contains 2 to ~31 signal frequencies, each with a certain phase relation, distributed over the frequency band of interest. Obviously, sophisticated test instruments are necessary to analyze all these signals with their interactions on each other.

Fig. 9 and *Fig. 10* show a typical multitone signal in the time- and frequency domain. It is important to know that the waveform of the time plot strongly correlates with the phase relations between its single frequencies. Since the max. amplitude of the time signal directly determines the dynamic range of both the DUT and the analyzer, a low peak value is both important and desirable.

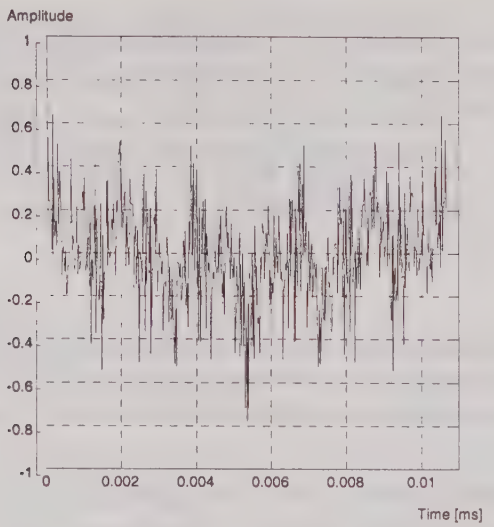


Fig. 11 Time Plot of a Multitone Signal

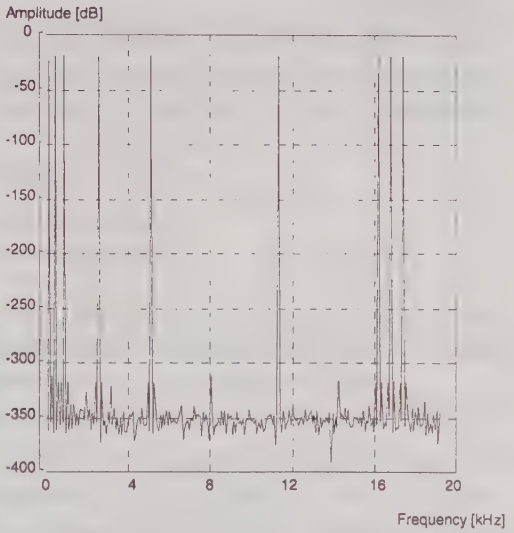


Fig. 12 Spectrum of a Multitone Signal

Obviously, it is necessary to characterize the time signal by an appropriate value in order to allow the optimization of its phase relations. The most suitable value for this purpose is the *Crest factor*, which is defined as

$$Crest\ factor = \frac{Peak_Value}{RMS_Value}$$

Equation 1 Crest Factor

For any (multitone) signal with given RMS value, the Crest factor will change with the peak value, which in turn depends on the phases of the signal components. An optimal distribution of the phases results in a low peak value of the resulting time signal and therefore a low Crest factor (refer also to chapter ***Phase / Crest Factor Optimization***).
NEUTRIK provides in its RT-EVAL software package a sophisticated algorithm to optimize the phases of a multitone signal. Please contact your local representative to get a free copy of this software.

Multitone Parameter

RT-1M is a digital processing system that analyzes the transmitted signal by using Fast Fourier Transformation (FFT) and calculates with its DSP all desired results out of the digitized samples.
For proper use and programming of *RT-1M* it is vital to understand the core parameter of this analysis as well as their relationships. Consequently, the most important definitions and formulas are explained below.

Sampling Rate

Every digitization process, i.e. conversion of an analog signal into a digital bit stream and vice versa, has to be accomplished at a certain *sampling rate* (number of samples per second). The sampling rate determines the analog bandwidth of the converter.

In *RT-1M*, the sampling rate is 48kHz, thus providing an analog bandwidth of up to 20kHz.

Blocklength

The number of samples, that are actually used for one FFT, is called *blocklength*. This value determines both the duration & the frequency resolution of a multitone signal. In RT-1M, the blocklength may be selected by the user in five steps from 512 to 8192.

$$MT\ Block\ Duration = \frac{Blocklength}{Sampling_Frequency}\ [s]$$

Equation 2 Duration of One Multitone Signal Block

Note **A RT-1M multitone burst always comprises several multitone signal blocks, thus resulting in a far longer duration than the *'MT Block Duration'*.**

The blocklength also defines the lowest detectable frequency of the incoming spectrum. For example, with a blocklength of 512 @ 48kHz sampling rate, a multitone block duration of 10.7ms results, corresponding to a min. frequency of Δf = 93.75Hz (see ***Equation 3***).

Furthermore, it is important to know that only signals with an integral number of periods (reciprocal value of the signal frequency) fitting into one blocklength may be properly analyzed by the FFT.

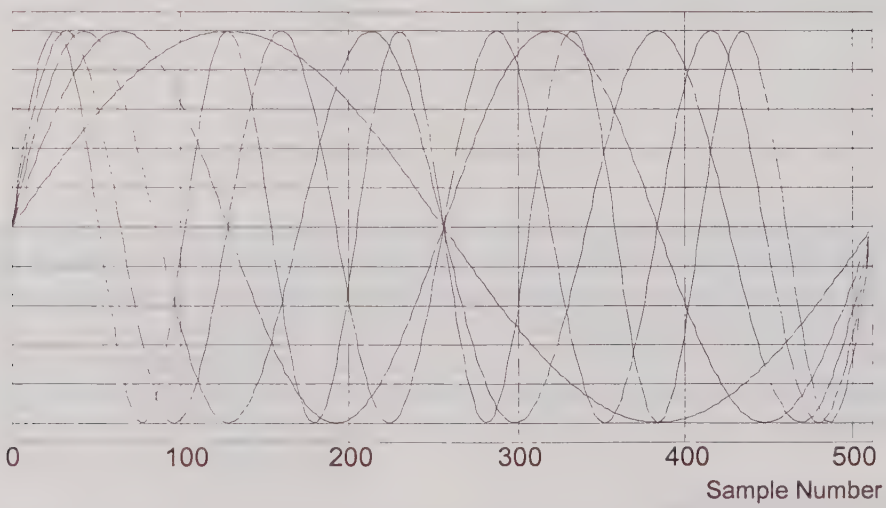


Fig. 13 The 5 Lowest Possible Time Periods @ Blocklength 512

In other words, only frequencies with an integral multiple of the lowest detectable frequency - called frequency spacing Δf - may be transmitted.

Frequency Spacing

The frequency spacing Δf corresponds to the lowest frequency that can be generated & analyzed. It defines the spectral resolution of the FFT and is calculated by following formula.

$$\Delta f = \frac{Sampling_frequency}{Blocklength} = \frac{48'000Hz}{Blocklength}$$

Equation 3 Frequency Spacing

Only frequencies with an integral multiple of Δf may be defined as *signal bins* (see below) of a multitone burst.

Example
Blocklength = 512 @ 48kHz sampling rate
⇒ Δf = 93.75Hz
⇒ available frequencies = *n* * 93.75Hz (*n* = integral number)

Bins

The frequencies, that may be transmitted in a multitone burst, are called *bins*. For a better understanding, three types of bins have been introduced.

- *Signal bins* are those bins (frequencies) that actually build the multitone signal.
- *Even bins* are all the bins (frequencies) that emerge from ***Equation 3***, i.e. the frequencies that may be used as signal bins in a multitone signal.
- *Odd bins* are an effect the internal FFT computation of *RT-1M*. They represent all bins halfway between the even bins, i.e. as if the frequency spacing would equal Δf/2.

The subsequent relations indicate the min. and max. available frequencies (*bins*) in a multitone signal at 8kHz / 48kHz sampling rate (f_s).

$$f_{\min} = \Delta f \quad \{\geq 20Hz \text{ may be generated only}\}$$

Equation 4 Minimum Signal Bin Frequency

$$f_{\max} = \Delta f * \left| \frac{20kHz}{\Delta f} \right| \quad \{\leq 20kHz \text{ may be displayed}\}$$

Equation 5 Maximum Signal Bin Frequency

Besides the above equations there are no other constraints for the definition of a multitone signal. This means you can use any bin representing a frequency below or equal to 20kHz as a signal bin. It is up to the operator what the intention of the signal bins is. Please refer also to chapter ***Signal Table***.

Phase / Crest Factor Optimization

In order to achieve a low Crest factor, RT-EVAL – an evaluation PC-program provided free of charge by NEUTRIK - offers a special feature that allows to optimize the phases of any multitone signal. The results can be loaded directly from or back into the *RT-1M* Generator.

Low Crest factors are important for two reasons. First, the peak level of the multitone signal raises the necessary input range for the analysis and thereby reduces sensitivity for the low-level signal components. Second, the low energy content of a multitone signal with high Crest factor may barely stimulate the DUT.

A non-optimized multitone signal may show Crest factors of up to 10 (20dB), while with a proper minimization algorithm, Crest factors as low as ~2 (6dB) can be found. This difference of 14dB can directly enhance or decrease the dynamic range of the analyzing system.

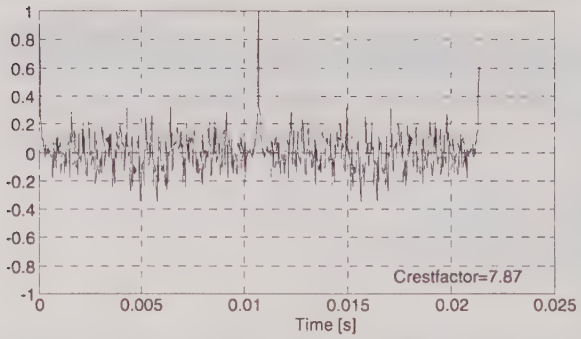


Fig. 14 Non-Optimized Multitone Signal

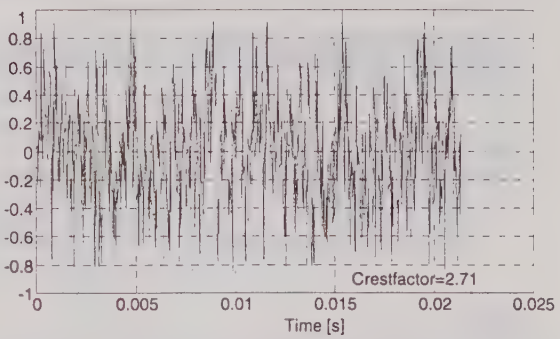


Fig. 15 Optimized Multitone Signal

Comparability of Multitone Measurements

One has to be aware that the results of multitone testing cannot be compared directly with conventionally acquired results. For instance, distortion products may appear over the entire band due to the fact that each signal bin produces harmonics and intermodulates with other signal bins. The strict separation between harmonic distortion and intermodulation cannot be guaranteed, since at certain signal bins some intermodulation products and harmonic frequencies may fall together, thus influencing the Distortion as well as the SINAD results..

However, a multitone signal comes much closer to a "real-world" signal than any single tone test signal. The results are in qualitative terms comparable with conventional measurement results as long as the specific theory behind multitone testing is considered. With a single tone stimulus, the achieved results are directly comparable to conventional analyzers.

Please refer to the corresponding application note, filed in the appendix of this manual.

Signal Table

RT-1M supports five different blocklengths. According to ***Equation 3*** to ***Equation 5***, each blocklength results in the parameter of ***Table 1***. Please observe that the minimum signal bin frequency is ≥20Hz and that the overall duration of a burst always is longer than of a block.

Blocklength	*Min. Burst Duration (without Header)*	*Typical Burst Duration*	*Generator Resolution*	*Analyzer Resolution*
512	154 ms	260 ms	93.8 Hz	46.9 Hz
1024	284 ms	390 ms	46.9 Hz	23.4 Hz
2048	344 ms	450 ms	23.4 Hz	11.7 Hz
4096	684 ms	790 ms	11.7 Hz	5.9 Hz
8192	854 ms	960 ms	5.9 Hz	2.9 Hz

Table 1 Available Blocklengths

Blocklength 512

Frequency spacing Δf	93.75 Hz	
Analyzer resolution	46.875 Hz	
Bin_Min (f_{min})	1	(93.8 Hz)
Bin_Max (f_{max})	213	(19.969 kHz)

Table 2 Signal Parameter with Blocklength 512 @ f_s=48kHz

Blocklength 1024

Frequency spacing Δf	46.875 Hz	
Analyzer resolution	23.4375 Hz	
Bin_Min (f_{min})	1	(46.9 Hz)
Bin_Max (f_{max})	426	(19.969 kHz)

Table 3 Signal Parameter with Blocklength 1024 @ f_s=48kHz

Blocklength 2048

Frequency spacing Δf	23.4375 Hz	
Analyzer resolution	11.71875 Hz	
Bin_Min (f_{min})	1	(23.4 Hz)
Bin_Max (f_{max})	853	(19.992 kHz)

Table 4 Signal Parameter with Blocklength 2048 @ f_s=48kHz

Blocklength 4096

Frequency spacing Δf	11.71875 Hz	
Analyzer resolution	5.859375 Hz	
Bin_Min (f_{min})	2	(23.4 Hz)
Bin_Max (f_{max})	1706	(19.992 kHz)

Table 5 Signal Parameter with Blocklength 4096 @ f_s=48kHz

Blocklength 8192

Frequency spacing Δf	5.859375 Hz	
Analyzer resolution	2.9296875 Hz	
Bin_Min (f_{min})	4	(23.4 Hz)
Bin_Max (f_{max})	3413	(19.998 kHz)

Table 6 Signal Parameter with Blocklength 8192 @ f_s=48kHz

Generator

RT-1M comprises a completely independent two-channel 16bit arbitrary generator. The digital section has its own high level microprocessor enabling the system to react flexibly to external events, communicate with various interfaces and reprogram the sample counter for the arbitrary generator

Block Diagram

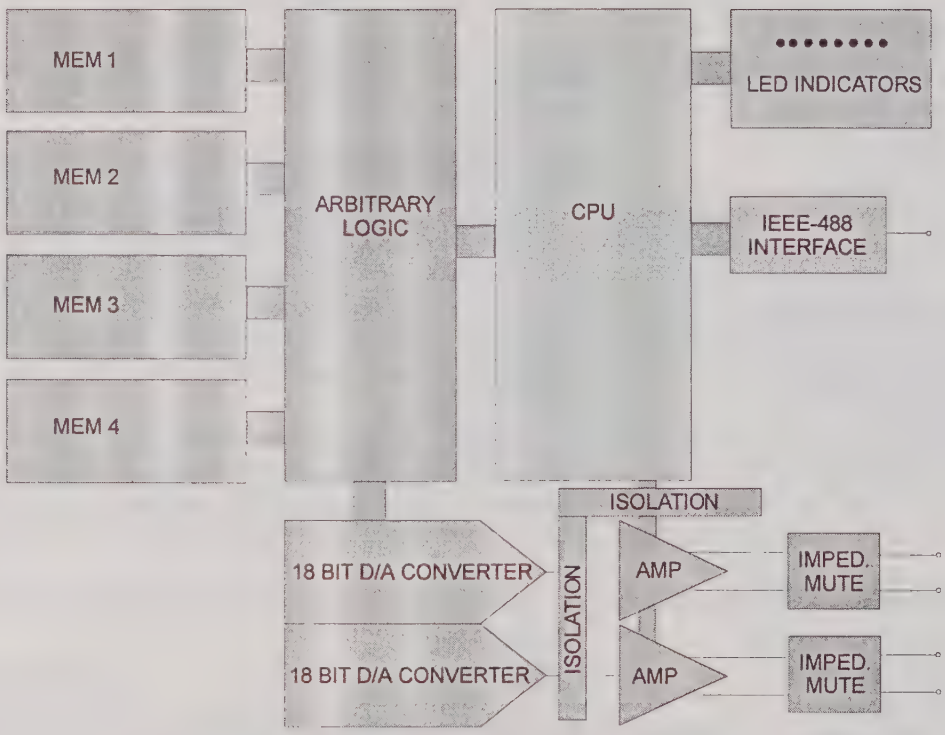


Fig. 16 Block Diagram Generator

Digital Section

The CPU reads the samples out of a non-volatile memory. The memory block provides capacity for four independent test signals, each with 16 bit resolution and any length defined in *Table 1*. Space is also provided for the header of each signal. The master clock is derived from a high precision crystal.

Analog Section

The two-channel analog output signal behind the D/A converters is fed into a reconstruction filter, cutting off all frequencies above 20kHz. On its way the signal also passes through an electrical isolation to keep the complete analog output section floating. The programmable output amplifier offers a balanced signal with 150Ω output impedance (unbalanced 75Ω) at any level in steps of 0.1dB between -60dBVp to +20dBVp.

Analyzer

The RT-1M analyzer consists of a two channel analog input stage, preparing the input signals for the conversion into digital format. With the converted signals an FFT analysis with the same blocklength as of the generated signal is performed. Further analysis of the acquired result may be done through individual programming.
Additionally, the analyzer also provides facilities to weight an input result with different weighting curves.

Block Diagram

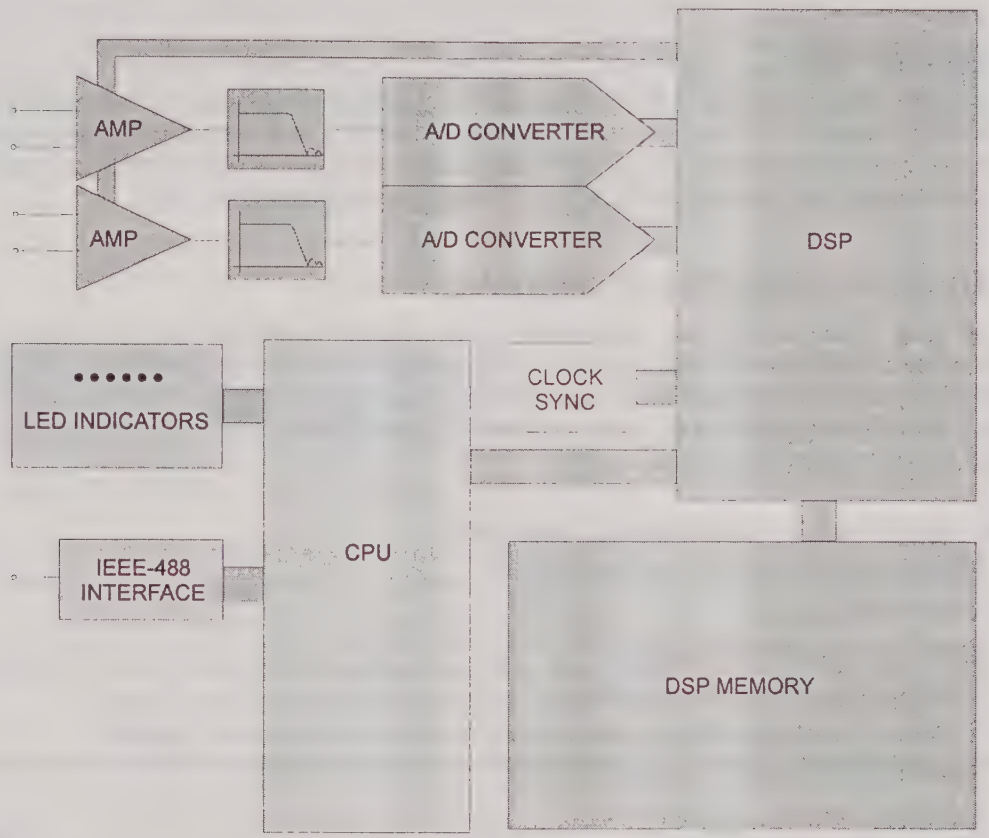


Fig. 17 Block Diagram Analyzer

Analog Section

RT-1M features two independent analog input stages with completely independent ranging facilities. The inputs are balanced with BNC and 4mm banana connectors at the front and rear panel. Input impedance is 100kΩ at all inputs. Levels can be handled from 60dBVp to +20dBVp with full dynamic range.

Filtering

RT-1M provides a set of software weighting and Emphasis filters. The filters have a gain of 1 and can be disabled or enabled. Only one weighting filter and the Emphasis filter may be engaged at a time. The current filters implemented are listed on the next page.

Filter type	Software
C-Message	☑
CCITT	☑
750µs Emphasis	☑

The commands ***INPut[1-2]:RANGe <Range> <Unit>*** and ***INPut:DEEMphasis*** allow to select them.

Digital Section

The digital section consists mainly of the DSP and a logic circuitry programmed into a FPGA. The DSP is used for all calculations - especially the FFT - and to control the range setting of the analog input amplifiers. The DSP is connected via a bus to the central processing unit which manages all communication to the PC and controls the system bus.

Definition of Multitone Signals

RT-1M may store up to four independent two-channel multitone signals with up to 31 frequencies in a non-volatile memory. This ensures that no programming or parameter loading is required before the generator can be operated. New signals can easily be loaded into one of the memory blocks using an IEEE output command. For the correct syntax please refer to ***OUTPut:MTONe:PARameter?***.

New signals must contain following information

- *RT-1M* memory-location to store the signal
- Name of the signal
- Blocklength (number of samples)
- Number of signal bins for channel 1
- Number of signal bins for channel 2
- Signal bin numbers of channel 1
- Signal bin numbers of channel 2
- Phases of the signal bins for channel 1
- Phases of the signal bins for channel 2

The *memory location* may be defined by a number from 1 to 4. *Name* is a user defined ASCII string with up to 8 characters. The *blocklength* has to be set to one of the values defined in ***Table 1***. The *number of signal bins* defines how many frequencies shall appear in the multitone signal for CH1 and CH2; the minimum is 1 (sinusoidal) signal, the maximum is 31 bins. The *signal bin numbers* have to be calculated according to ***Equation 7***. Two blocks of *phase* values for CH 1 and CH 2 terminate the definition of a multitone signal.

All signal bins have identical amplitudes. The user has the choice either to set the *overall output level* of the multitone signal or, alternatively, the *signal bin level*. Regardless of this choice, these values may be expressed as peak or RMS levels in linear or logarithmic units (Vp, V, dBVp, dBV).

The overall output level of a multitone signal may be queried at any time. The same goes for the actual Crest factor, that may be queried with the command ***OUTPut[1-2]:MTONe:CRESt?*** or calculated by using ***Equation 1***. With these two values, the signal bin level may be calculated according to

$$U_{bin_{RMSF}} = \frac{U_{out_{RMS}}}{\sqrt{n}} \quad with\ n = total\ number\ of\ signal\ bins$$

Equation 6 Bin Amplitude

Following example shall illustrate the signal definition procedure. The multitone signal shall have three signal bins at 300Hz, 1kHz and 3kHz. Both channels are identical. The name of the signal is "Telefon". Since the three frequencies are fairly wide apart, we may use a blocklength of 512, resulting in a frequency spacing of 93.75Hz. To calculate the signal bin numbers, refer to ***Equation 7***

$$Bin_n = Round(\frac{f_n}{f_{min}}) = \frac{300Hz}{93.75Hz} = 3$$

Equation 7 Bin Number

Consequently, the bins equaling 300Hz, 1KHz and 3KHz have the numbers 3, 11 and 32. The definition of the phases can be done manually or by using the Crest factor optimizer of RT-EVAL. Finally, the table may look as follows.

```
1,"Telefon",512,3,3,3,11,32,3,11,32,-3.141,1.234,0.707,0,0.810,0.111
```

The duration of this multitone signal (not considering the header explained below) is the reciprocal value of 93.75Hz which is 10.67ms.

ATTENTION **Do never define *exclusively* the three signal bins @ 562.5Hz, 1406.25Hz and 3.0kHz as multitone signal since these three frequencies form the trigger of a multitone burst header.**

Header

Each multitone burst is preceded by a header comprising trigger and clock synchronization.

The standard *trigger* signal has a duration of 42ms and consists of 5 fixed frequencies in the voice band with different levels. By receiving this frequency / level pattern a listening analyzer recognizes a *RT-1M* multitone signal and wakes up. The pattern has been selected in a way that the false-triggering rate due to voice, music or other synthesized signals, interpreted as multitone signal, is < 10^{-6}.

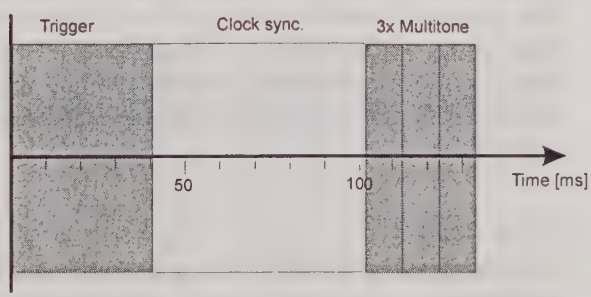


Fig. 18 Multitone Signal with 5 Bursts as Example

Additionally, a *pretrigger* signal may be added in order to allow the DUT to stabilize before transmission of the rest of the multitone signal. See also command ***OUTPut[1-2]:LEVel <Level> <Unit>***.

During the *Clock Sync* period (SYNC block) with a fixed length of 64ms, the analyzer may adjust its sampling frequency to the transmitted clock frequency (3kHz). This ensures that frequency shifts, generated by the DUT (modulators / demodulators or tape machines with speed differences) or slightly different clock frequencies of a separated generator / analyzer pair are eliminated automatically.

Multitone Signal

Right after the header information follows the *multitone signal* itself, i.e. transmission of the signal bins. The duration of the multitone signal depends on the block length as defined in ***Table 1***. The multitone signal is transmitted at least 3 times and may be repeated by applying the command ***OUTPut:MTONe:MTONelength***. For instance, several multitone blocks may be transmitted before the analysis starts, in order to stabilize the DUT and to let transients disappear. The analysis itself requires a minimum of two blocks.

Data Acquisition

Wake-up Sequence

The *RT-1M* analyzer continuously executes a FFT of the input signal. As long as there is no signal or any non-correlated audio information, no action is started. But as soon as the analyzer detects a header, i.e. the *RT-1M*-specific frequency / level pattern in the input signal, it wakes up and records the incoming multitone signal.

Please notice that the trigger signal can be detected up to -20dB below the set range. That means for example with an input range set to -6dBu the trigger can be detected from levels as low as -26dBu.

Synchronization Mode

Normally, the analyzer of *RT-1M* uses the internal sample frequency clock of the generator. This mode should be used for all applications where no frequency shifts occur on the signal transmission path.
However, in cases where the device under test (DUT) changes the frequency of the transmitted signal, the analyzer has to synchronize itself onto the incoming signal itself. For this purpose, each header of a multitone burst contains a SYNC block, providing a fixed frequency, onto which the analyzing DSP may synchronize its sampling clock. This feature and the choice, whether a header shall be transmitted at all, may be activated with command ***INPut:SYNC [INTernal\|INTNoheader\|EXTernal\|EXTNoheader]***, offering the four following modes.

INTernal

The analyzer is linked to the generator clock of the same unit and the multitone signal is preceded by a header (trigger & SYNC block). This mode may be chosen if the multitone burst is generated in the same unit where it is analyzed and if no major frequency shifts occur in the DUT. The burst is initiated with command ***OUTPut:MTONe:STARt*** and transmission must not show a delay of more than 1s.

INTNoheader

Again, the analyzer is linked to the generator clock of the same unit, but no header is transmitted. The benefit of this mode appear in noisy environments, where the trigger cannot be detected, and for analysis of signals being generated by the DUT itself. However, the max. allowable transmission duration is 50ms, i.e. the multitone burst must 'arrive' at the analyzer at latest after this time from the moment of its initiation.

EXTernal

In case of expected clock frequency differences between the generator and analyzer the user has to activate the EXT mode. Frequency shifts appear e.g. in combination with analog tape recorders, where the recording and the playback speed are not identical, or due to local separation of generator and analyzer. Up to 1s transmission time is allowed.

EXTNoheader

This mode may be used after transmission of several multitone burst transmissions in mode EXT only. The analyzer synchronizes itself onto the SYNC blocks of these preceding multitone bursts, before it eventually gathers the burst in mode EXTnoheader.

Gathering Data

After triggering and synchronization, the analyzer waits one period of the multitone burst to let the transients of the DUT disappear before it starts with a two-block FFT. This calculation takes - depending on the block length - between 48ms and 190ms. The analysis includes

- Decoding of the bit stream to get two stereo signals
- Windowing with Hanning window (where necessary)
- Organization of bits (bit reverse organization of results)
- Calculation of level and phase from the complex spectrum

The calculated vector is placed in the result area of the memory and the DSP is ready for the next acquisition.
If the user queries for measurement results, the CPU reads these stored data from the internal memory and computes the required results out of them. This process requires considerable computations since all the bins have to be read, squared and summed up for the results calculation. As soon as this process is finished, the results are transmitted and thus available for further processing.

Signal Analysis & Result Queries

Level

One core requirement of audio testing is the analysis of the *frequency response* of the DUT. With the multitone approach, this goal is achieved in one step by measuring the returned signal bin levels instead of sweeping a single sine signal through the frequency band of interest.

In practice, the frequency response can be obtained from a transmitted multitone signal by plotting the received signal bin level values. Please notice that this analysis considers the energies of the signal bins only, but not the distortion + noise energy in the bands between the signal bins.

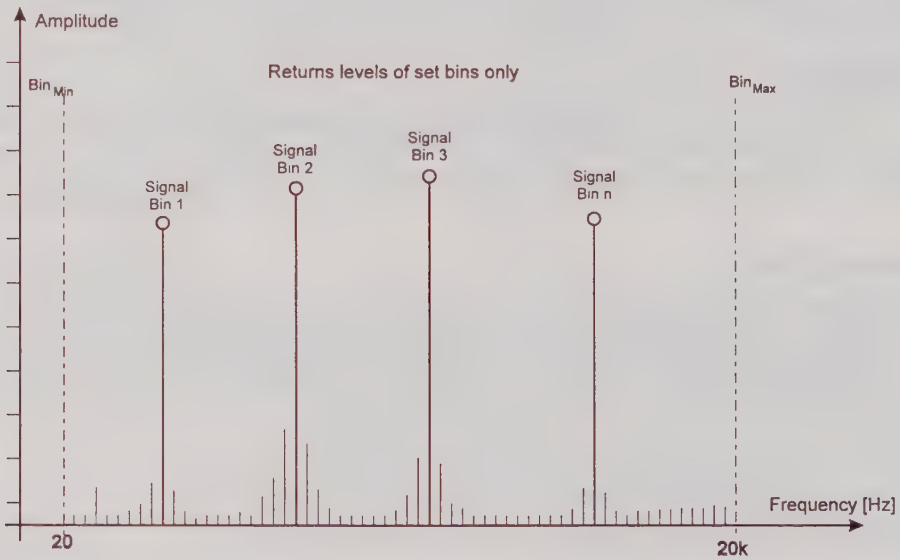


Fig. 19 Level Plot

Keep in mind, that the *overall input level*, i.e. the total energy of all received *signal bin + (unused) bin levels* would correspond to the RMS level of the received multitone signal (signal bin levels + distortion + noise).
However, this value is of almost no interest for the characterization of a DUT, since it reflects its overall attenuation / amplification only, but not the frequency response.

Distortion

Basically, *distortion* is a measure to characterize the nonlinear behavior of a DUT, i.e. the degree of how it generates new signal components at other frequencies than the one(s) of the stimulating signal. Therefore, The *RT-1M* returns as distortion results the *total distortion + noise energies* (TD+N) for the bands between the signal bins of a multitone signal.

Remains the question, in which way *RT-1M* actually calculates the TD+N values in the frequency bands of interest. The answer can be given by considering the equations for the RMS and RSS value.

RMS and RSS Value

Purely analog test instruments evaluate the distortion energy as *RMS* voltage (Root Mean Square) by summing up all received signal components V_i according to following equation.

$$V_{RMS} = \sqrt{\frac{\sum_{i=1..n}(V_i)^2}{n}} \quad with\ n = number\ of\ signal\ components$$

Equation 8 RMS Calculation

Unfortunately, when applying this formula on the discrete spectrum of a FFT analysis, the result correlates in inverse proportion to the blocklength / number of bins in the respective band. Therefore, to calculate the TD+N result out of a digitized signal, the *RSS* value (Root Sum Square) has to be used.

$$V_{RSS} = \sqrt{\sum_{i=n..m}(V_i)^2} \quad with\ i = counter\ over\ all\ bins\ (n..m)$$

Equation 9 RSS Calculation

The accuracy of this approach can be proved with any spectral analyzer. The better the resolution (i.e. the higher the blocklength), the lower is the amplitude of a single bin, since the total energy of the band is constant. Consequently, the summing-up of the bins always result in the same value, regardless of the chosen resolution (blocklength).

Interpretation of TD+N

To interpret the TD+N value correctly, it has to be considered that this result slightly differs from a conventionally measured *THD+N* value. With conventional THD+N analysis, a single tone stimulates the DUT. This frequency component is subtracted from the received signal after transmission. The ratio of the remaining level to the total input level gives the THD+N and *SINAD* result respectively.

On the other hand, the transmission of a multitone stimulus will result in the appearance of many harmonics and intermodulation products. However, it is neither possible to relate any of these signal components to a certain signal bin of the original multitone signal, nor to differentiate the received signal between harmonics and intermodulation products.

Distortion Plot

Fig. 20 shows a typical distortion plot, derived from the returned distortion results of *RT-1M*.

- The first value in the plot *D1* equals the RSS result (TD+N value) of the band between the first bin ≥20Hz up to the last bin < SignalBin#1.
- All further results *Dn* represent the bands between the first bin > SignalBin#n up to the last bin < SignalBin#n+1.
- The last distortion result represents the band between the first bin above the highest signal bin up to the last bin ≤ 20kHz.

Please notice, that both the even & odd bins of the received signal are considered for the TD+N calculation.

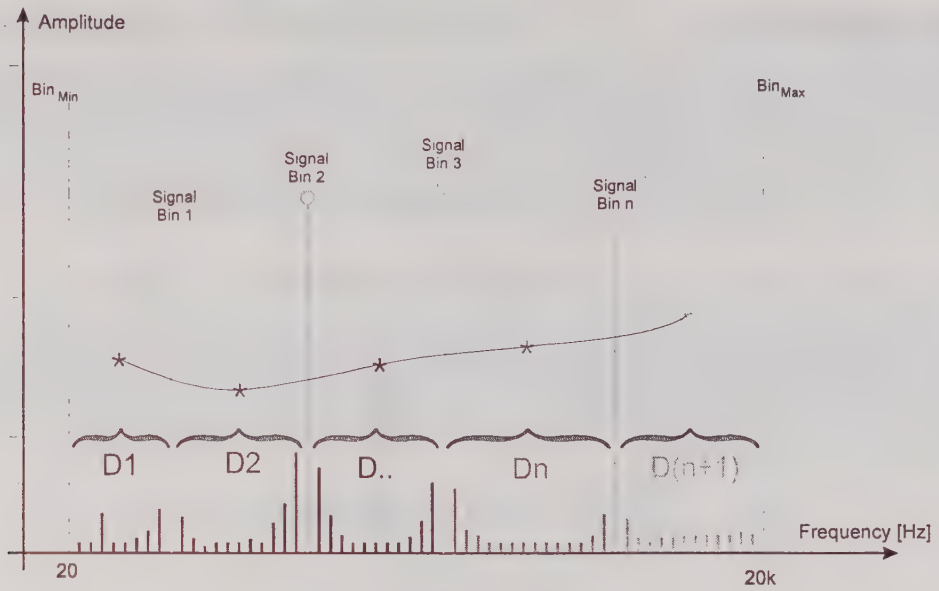


Fig. 20 Distortion Plot

Full Band TD+N Measurement

To evaluate the TD+N value in the full frequency band (20Hz-20kHz), following equation has to be applied.

$$TD+N_{FullBand} = \sqrt{D_1[V]^2 + D_2[V]^2 + ... + D_n[V]^2}$$

Equation 10 Full Band TD+N

wherein D_1-D_n are the returned distortion results, expressed in [V].

THD+N Calculation

To evaluate the THD+N value of a DUT, the following requirements have to be met.

- Stimulation of the DUT with a single bin signal.
- Calculation of the THD+N value (in %) according to

$$THD+N\,[\%] = \frac{\sqrt{D_1[V]^2 + D_2[V]^2}}{\sqrt{D_1[V]^2 + L_1[V]^2 + D_2[V]^2}} * 100$$

Equation 11 THD+N Calculation

with D_1 = distortion between 20Hz and the signal bin, D_2 = distortion between the signal bin and 20kHz and L_1 = received signal bin level.

MT-SINAD

For some applications, the SINAD result - being the reciprocal of THD+N - is required.

$$SINAD = \frac{Signal + Noise + Distortion}{Noise + Distortion}$$

Equation 12 SINAD Definition

Obviously, to get a true SINAD result, it is necessary to stimulate the DUT with a single sine tone only. Otherwise, i.e. if a multitone signal is applied, intermodulation products would appear, thus increasing the *Noise+Distortion* value. Nevertheless, it is also possible to calculate the SINAD result out of a transmitted multitone signal. However, in order to avoid misunderstandings, this result is called MT-SINAD herein.
Actually, with *RT-1M*, just use the query command ***MEASurement[1¦2]:MTSinad?***, to get the calculated value.

In practice, the MT-SINAD result may differ slightly from a conventionally measured SINAD value, due to intermodulation products between the signal bins. However, in qualitative terms, the results are equal as proven in numerous setups.

RSS Selective Measurement

The
MEASurement[1-2]:SELectiverss? <binstart> <binstop> command allows to query the TD+N result of a user-defined band anywhere between 20Hz and 20kHz. Both the lower and the upper border of this band may be set freely to any bin number - they don't have to be identical to the signal bins of the transmitted multitone signal.

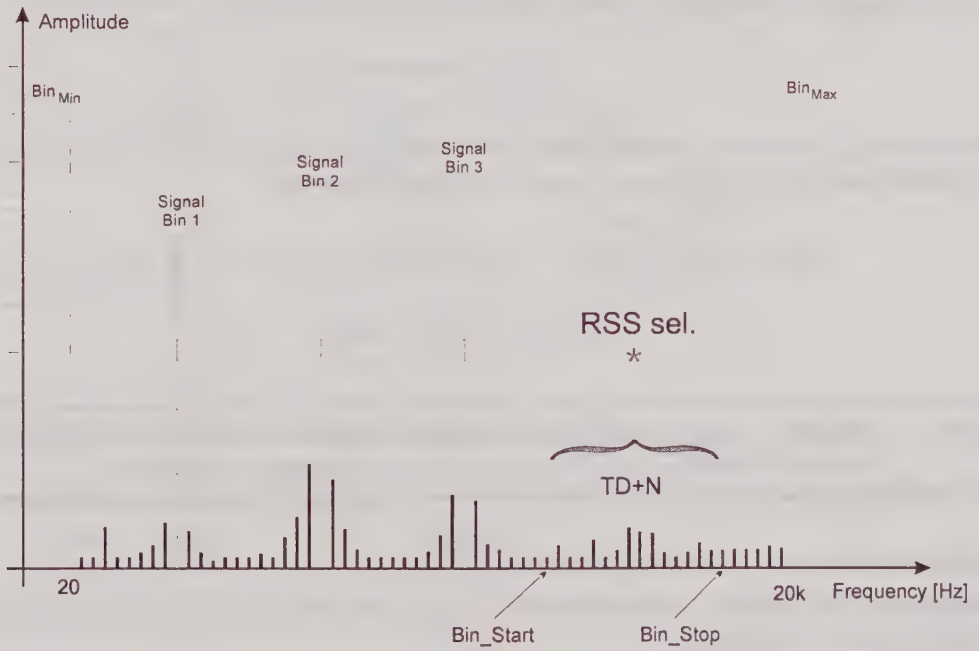


Fig. 21 RSS Selective Plot

NOTE	**Be aware, that if a signal bin is within the band of interest, the RSS selective result will represent the *signal bin level + distortion + noise*.**

The RSS selective feature is especially helpful, if a certain component of a received signal shall be investigated. For instance, after transmission of a single tone signal, it allows to evaluate the individual harmonics of the fundamental frequency.

Noise

As for distortion analysis, the noise measurement divides the frequency band in subbands, split by the signal bins, and calculates the noise values of these subbands.

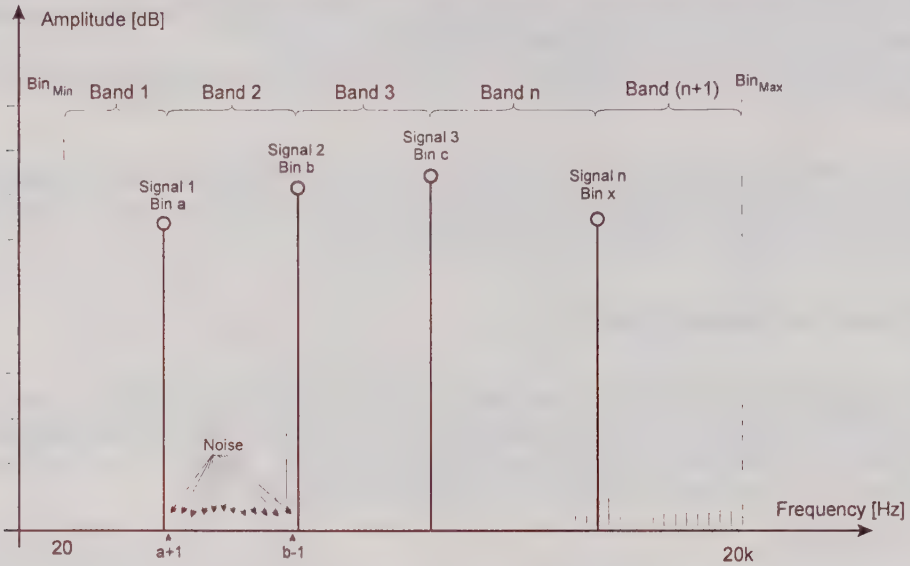


Fig. 22 Noise Plot

Consequently, a multitone measurement with *n* signal bins results in *n+1* noise values, each calculated internally by *RT-1M* according to the following formula.

$$Noise_i = \sqrt{2 * \sum_{i=a+1}^{b-1} \left(U_{2i-1}\right)^2} \quad = RSS\ value\ of\ all\ odd\ bins\ in\ a\ band$$

Equation 13 Noise Calculation

NOTE	***Equation 13*** **describes the internal noise calculation of *RT-1M*, i.e. the actually returned noise results must not be re-calculated in any way.**

Full Band Noise

MeasurementTo evaluate the noise value in the full frequency band (20Hz-20kHz), following equation has to be applied.

$$N_{FullBand} = \sqrt{N_1[V]^2 + N_2[V]^2 + ... + N_n[V]^2}$$

Equation 14 Full Band Noise

wherein N_1-N_n are the returned noise results, expressed in [V], of any multitone measurement.

Crosstalk

The Crosstalk Plot may be calculated only if a stereo signal is transmitted. This stereo signal must have separate bins set in the 2 channels in a way that the respective bins remain unused in each other channel. In case of bad channel separation of the DUT, the unique frequencies of channel "A" talk into channel "B", i.e. they appear in the received signal of channel "B" and vice versa.
The crosstalk value is the ratio of the unused bin level in channel "B" and the active bin level of channel "A" at the same frequency. It is expressed in % or dB.

$$Crosstalk_i^{LEFT} = \frac{Unused_Bin_ChB_i}{Set_Bin_ChA_i}$$

Equation 15 Calculation of Crosstalk

As an example, we may assume that a signal bin with 10dB @ 1kHz is transmitted via channel "A", while at channel "B" the received bin level @ 1kHz equals -30dB. Consequently, the crosstalk from channel "A" to channel "B" @ 1kHz is 1% or -40dB.

Please note that noise increases the crosstalk value and thereby falsifies the measurement.

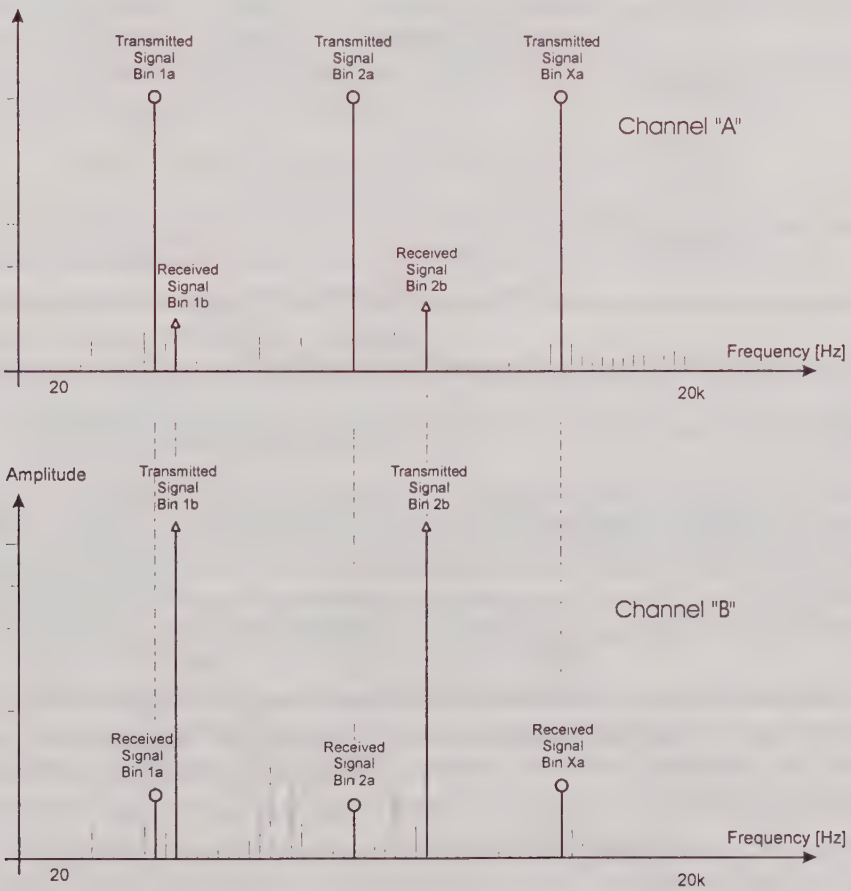


Fig. 23 Crosstalk Plot

Phase

Since the analyzer knows all information about the transmitted multitone signal from the generator, also the phases of the signal bins are available for further analysis. Therefore, the analyzer may calculate any changes of inter-channel phase relations at each common signal bin of the 2-channel test signal.

$$\varphi_i = \varphi(U_i^{Left}) - \varphi(U_i^{Right})$$

Equation 16 Phase Calculation

However, the exact phase shift between generator output and analyzer input cannot be calculated due to the unknown time delay of the DUT.

DTMF Mode

The DTMF option extends the measuring capabilities of RT-1M in the field of phone testing. It allows to receive & analyze the standardized DTMF (Double Tone Multiple Frequency) tones on channel 1.

Every key of a standard 4x4 phone keypad is represented by a dual tone. These tones comprise the indicated frequencies as shown in ***Table 7***.

	1209Hz	1336Hz	1477Hz	1633Hz
697Hz	1	2	3	*a*
770Hz	4	5	6	*b*
852Hz	7	8	9	*c*
941Hz	*	0	#	*d*

Table 7 DTMF Signal Coding

For instance, the DTMF tone for key #6 is put together of the two frequencies 770Hz & 1477Hz.
The meaning of the four 'empty' keys *a-d* in the last row may be user-defined.

The DTMF mode of RT-1M may be started and reset by using command ***MEASurement1:DTMF:STARt***. From then on, the unit continuously monitors the input channel 1 in parallel to any other operation, and stores all received DTMF tones in an internal buffer. This 32 keys wide buffer may be queried by command ***MEASurement1:DTMF?***. To clear the contents of the buffer, command ***MEASurement1:DTMF:STARt*** has to be sent to the unit.

The input range of channel 1 must be adjusted to the level of the DTMF tones to be analyzed. Please notice that an overload, caused by an incoming DTMF signal, will not be detected, i.e. the unit will not generate an error message. Furthermore, no DTMF tone analysis will be possible in such a case.

Broadcast Mode

The broadcast mode allows to let the analyzer of a RT-1M unit wait for an incoming multitone burst that has been generated by another, remote RT-1M unit (generator & analyzer are physically apart). By this, it becomes possible to measure e.g. the characteristics of a transmission line.

Following restrictions have to be considered on behalf of the broadcast mode.

- The measurements under the broadcast mode can be done in one direction only at a time. In order to return a multitone burst in the opposite direction, i.e. from the previously used analyzer to the generator, the operation mode of both units has to be changed.
- The generator & analyzer must be controlled each by a PC through a GPIB interface.
- The transmitted multitone signal must be defined identically on the generator & analyzer.
- In order to avoid false triggering, it is vital to thoroughly understand and apply the trigger configuration as well as the setting of a proper output level and input range in the generator and analyzer.

Mode of Operation

The broadcast mode of RT-1M is based on the command ***INPut:TRIGger:ARMed***. If sent to the unit, this instruction sets the analyzer to a state where it waits until it detects an incoming RT-1M trigger and receives the connected multitone signal.
The trigger must have been generated by another RT-1M instrument and has to match the trigger conditions defined in the analyzing unit.

Setup

The complete procedure to set up a broadcast transmission test with RT-1M may be summarized as follows.

1. Install the generator and analyzer at the intended locations and control each of them with an own PC through GPIB IEEE interfaces.
2. Connect the two units with the ends of the transmission line to be measured.
3. Write an appropriate program to control the units. Optionally, you may also install RT-EVAL V1.60 or higher on both host PCs.
4. Define a multitone signal according to the specific demands of the test (available bandwidth, number of bins, signal duration etc.) identically on both the generator and analyzer. Don't forget to optimize the Crest factor of the signal (e.g. by using the Crest optimizer of RT-EVAL).
5. In the analyzer, set the trigger configuration to TIGHT by using command ***INPut:TRIGger:CONFiguration [LOOSE|TIGHT|USER]***.
6. Set the SYNC mode of the generator to INTernal with command ***INPut:SYNC INTernal***.
7. Set the output level of the generator approximately to the level of the broadcast signal. Make sure that no clipping occurs.
8. Set the SYNC mode of the analyzer to EXTernal with command ***INPut:SYNC EXTernal***.
9. Adjust the input range of the analyzer to the incoming signal level. To do this, connect the analyzer to the transmitted broadcast signal and reduce the input range until the Overload LED lights up. Increase the input range by +6dB from this value in order to provide enough headroom.
10. Set the analyzer to the armed mode with command ***INPut:TRIGger:ARMed***.

11. Interrupt the broadcast signal and transmit the multitone burst with command *OUTPut:MTONe:STARt*.
12. It is recommended to transmit the burst at a defined time, so that the operator of the analyzer realizes immediately, whether the trigger has been detected or not.

If no successfull line measurements are possible, read the chapter ***Application Hints / Troubleshooting*** (p. *37*) to check possible causes and work out solutions.

Trigger Configuration

The most important topic of broadcast mode measurements with *RT-1M* is the definition and application of an appropriate trigger. For this purpose, three trigger configurations are provided.

- *LOOSE* - standard configuration for industrial applications (noisy signals with a poor dynamic range, or internal link between generator & analyzer). The trigger condition is met rather easily, i.e. false triggerings have to be expected if the multitone signal is introduced into an ordinary broadcast program etc.
- *TIGHT* - special configuration for broadcast applications. The trigger condition has been tightened by far vs. *LOOSE* in order to avoid false triggerings. Requires an accurate setting of the generator output level and analyzer input range.
- *USER* - this parameter allows to define the trigger condition according to user-specific demands. However, since this application requires a very thorough and detailed understanding of the whole triggering complex, this approach is for very advanced users only, who have a profound understanding of all possibilities and their consequences.

ATTENTION **Improper configuration of the USER trigger may result in a 'always' or 'never' condition, where the analyzer triggers on almost every incoming signal (music, speech etc.) or never recognizes any trigger, even if it is a correct one.**

The trigger signal of a *RT-1M* multitone burst comprises three signal bins at different frequencies and with individual levels. In order to avoid false triggerings, the receiving *RT-1M* permanently monitors the input signal on strictly this pattern. Furthermore, the analyzer checks whether two more, predefined signal bins are 'empty', i.e. whether no level can be detected at these two frequencies. If this is the case, the analyzer recognizes the incoming signal as a *RT-1M* multitone burst and triggers to it.

Fig. 24 visualizes the characteristic of a *RT-1M* triggersignal. The bottom bars (T) at the frequencies 1, 3 and 5 represent the set signal bins and their amplitudes, defined against the ground

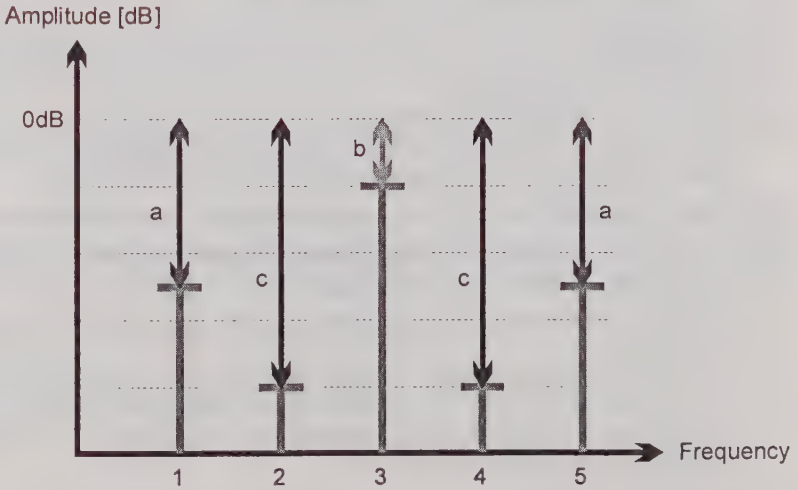


Fig. 24 Trigger Definition

level of the generator, whereby signal bin 1 and 5 have identical amplitudes. The frequencies 2 & 4 represent the empty bins.
Obviously, the levels of the five signal bins, together with their frequencies, make the uniqueness of the RT-1M trigger signal.

The application of the User trigger allows to individually define the 'headroom' between the 0dB line and the bottom bars (**T**). However, this is a very delicate operation, and therefore not recommended for new users of RT-1M. Anyway, in case that this feature truly has to be used, please refer to the explanations of the commands ***INPut:TRIGger:CONFiguration ...*** and ***INPut:TRIGger:USRConfiguration ...*** as well as to the helpfile of the RT-EVAL software package.

Remains the question about the reference level of the analyzer, since especially for long-distance transmission lines, this instrument cannot use the same reference voltage potential as the generator.
The solution is to assume the currently set input range of the analyzing RT-1M unit as reference level. This level equals the max. detectable amplitude of all incoming signals (all higher levels would be clipped), and is represented by the 0dB line on top of ***Fig. 24***.
Consequently, all received signals will be analyzed against 0dB. Applied on the trigger detection criteria, this means that the level pattern of an incoming multitone trigger must be within a certain range, defined by the trigger configuration of the analyzer.

Application Hints / Troubleshooting

To execute measurements in the broadcast mode is probably one of the more demanding procedures when working with RT-1M, mainly because of the remote location between the generator and analyzer, i.e. the sender and receiver of the multitone burst.

Nevertheless, by considering both the instructions listed in chapter ***Setup*** (p. *35*) and following hints, it shouldn't become a major problem to establish a properly working set up.

- The most effective approach to successfully execute a first test run, is to place the sender & receiver not too far apart (e.g. in the same room), however, with both units already being controlled by individual PCs. Such a setup may probably not include a long transmission line, but is ideally suited to adjust the required settings of the majority of the involved systems to allow a proper measurement.
- For the first signal transmissions / measurements, reduce the number of involved stages to a minimum, to simplify the search for possible errors. As soon as the first successful tests are completed, the number of systems in the signal path may be increased stepwise, and the respective settings may be optimized to the actual demands.
- A very helpful tool to find out possible problems is to use a monitor speaker to make the transmitted multitone burst audible at the different stages of the line. Consequently, by listening to the sound of the burst, the operator may simply localize critical components and optimize their transmission behaviour.

The most frequent obstacle in the broadcast mode is the 'refusal' of the analyzer to trigger to the incoming multitone burst. This effect is usually caused by improper adjustments of the involved RT-1M generator / analyzer, or by sound enhancing instruments (e.g. equalizer, compressor, limiter, compander etc.) on the transmission line, which modify the trigger signal in a way, that it can't be recognized anymore.

Consequently, the efforts to overcome missing triggerings have to focus on the proper adjustment of the sending and the receiving RT-1M, as well as on the mutual optimization between the trigger signal and the sound enhancing systems.

Possible Cause	*Effect*	*Suggested Solution*
Generator output level too low *and/or* Analyzer input range too high	The incoming trigger signal level doesn't match vs. the analyzer sensitivity, so that the trigger can't be recognized	Increase the generator output level or decrease the analyzer input range stepwise
Generator output level too high	The trigger signal is modified by sound enhancing units in a way, that it can't be recognized any more by the analyzer	Reduce or attenuate generator output level
Analyzer input range too low	The input stage of the analyzer is too sensitive, i.e. overloaded, and therefore can't recognize the incoming trigger	Increase input range of analyzer stepwise
Very strong sound enhancing effects or a low quality of the transmission line	Distortions, noise or sound enhancing effects modify the trigger signal in a way, that it can't be recognized any more by the analyzer	Switch Off all sound enhancing systems during the transmission of the multitone burst
Multitone signal not identical on generator & analyzer	Analyzer triggers correctly, but can't acquire a reasonable result	Set the identical signal bins in the active multitone signal of the generator & analyzer

Table 8 Broadcast Mode Troubleshooting

4 PROGRAMMING

Communication via the IEEE-488 interface allows complete remote control for all functions of *RT-1M*.

Command Structure

IEEE-488.1 Compatibility

The IEEE interface function set implemented in *RT-1M*. The compatibility level is given in *Table 9*.

Function	*Implemented*	*Notes*
Source handshake	SH1	Complete capability
Acceptor handshake	AH1	Complete capability
Talker	T6	No talk-only mode
Talker (extended)	TE0	No capability
Listener	L4	No listen-only mode
Listener (extended)	LE0	No capability
Service request	SR1	Complete capability
Remote local	RL0	Only local lockout
Parallel poll	PP0	No capability
Device clear	DC1	Complete capability
Device trigger	DT0	No capability
Controller	C0	No capability

Table 9 IEEE 488.1 Compatibility

IEEE-488.2 Commands

RT-1M currently does not support all IEEE-488.2 commands. These might be implemented at a later state.

Command Summary

Following commands are currently available to control *RT-1M* system. The commands are divided into four subsystems.

Subsystem	*Function in RT-1M*
SYSTEM	Control of RT-1M
INPUT	Control of analyzer input section
OUTPUT	Control of generator output section
MEASUREMENT	Query for measurement results
*	Device Status

Table 10 Subsystem Definition

Most of the Parameter have to be completed with channel or signal information.

SYSTem:	RESet	
SYSTem:	ERRors?	
SYSTem:	INFormation?	
INPut:	FRONt	
INPut:	LINK	
INPut:	RANGe	
INPut:	SYNC	
INPut:	SWFilter	
INPut:	DEEMphasis	
INPut:	TRIGger:	ARMed
INPut:	TRIGger:	ARMed?
INPut:	TRIGger:	BREak
INPut:	TRIGger:	CONFiguration
INPut:	TRIGger:	USRConfiguration
INPut:	TRIGger:	USRConfiguration?
INPut:	STATus?	
OUTPut:	MTONe:	PARameter
OUTPut:	MTONe:	ACTive
OUTPut:	LEVel	
OUTPut:	BINlevel	
OUTPut:	MTONe:	PRETriggerlength
OUTPut:	MTONe:	MTONelength
OUTPut:	FLOAT	
OUTPut:	MUTe	
OUTPut:	MTONe:	STARt
OUTPut:	MTONe:	CONTinuous
OUTPut:	MTONe:	PARameter?
OUTPut:	MTONe:	NAME?
OUTPut:	MTONe:	BLOCklength?
OUTPut:	MTONe:	CRESt?
OUTPut:	STATus?	

MEASurement:	LEVel:	UNIT
MEASurement:	LEVel?	
MEASurement:	DISTortion:	UNIT
MEASurement:	DISTortion?	
MEASurement:	MTSinad?	
MEASurement:	SELectiverss:	UNIT
MEASurement:	SELectiverss?	
MEASurement:	NOISe:	UNIT
MEASurement:	NOISe?	
MEASurement:	PHASe:	UNIT
MEASurement:	PHASe:	SCALe
MEASurement:	PHASe?	
MEASurement:	CROSstalk:	UNIT
MEASurement:	CROSstalk?	
MEASurement:	DTMF:	STARt
MEASurement:	DTMF?	
*STB?		
*OPC		
*OPC?		
*CLS		
*ESE		
*ESE?		
*SRE		
*SRE?		
*ESR?		
*PSC		
*PSC?		
*IDN?		
*RST		
*TST?		
*WAI		

Descriptive Symbols

Following terms are used in the command description.

Symbol	Description
[ ]	Used to enclose one or more optional Parameter to control RT-1M. Omitting the default Parameter causes the system to use the default action.
{ }	Used to enclose one or more Parameter that may be included several times.
?	Indicates a query by appending the question mark to the last keyword in a command. Not all commands have a query; some are only query commands.
¦	Read this signal as an "OR". It is used to separate alternative Parameter.
< >	Used to enclose an SCPI defined parameter
:	Used to separate elements of a RT-1M command
;	Used to separate commands in a command list
,	Used to separate arguments in an arguments list
( )	Used to indicate a range of suffixes available
💻 →	String is sent from the controller to RT-1M
→ 💻	Returned string from RT-1M to the controller

Table 11 Symbol Description

RT-1M accepts only the short or the exact and full form of the statements. Sending a command that is neither will generate an error. In following command list, the CAPITAL letters indicate the short form to help reduce the required typing. However, the RT-1M parser accepts both lowercase and UPPERCASE commands, i.e. it is not case sensitive.

Command Notation

In the listing of RT-1M commands, descriptive headings are used to divide the information into easily readable parts. The used headings and the contents are shown below. If a heading does not apply on a command, it is not listed.

Use	What the command does and additional information is given in the heading.
Answer	Lists the possible answers on a query and their types (*integer*, *float*, *boolean*, *string*).
Parameter	Description of the Parameter to be set and their types (*integer*, *float*, *boolean*, *string*).
Range	List of the available Parameter and their types (*integer*, *float*, *boolean*, *string*).
Default	Description of the default parameter. After a RESET, all Parameter in an instrument are set to their default values.
Unit	Specification of the available parameter units.
Resolution	Definition the step size of a <Numeric_Value>
Query	Indicates the query command, corresponding to the described command.
Example	Command examples are provided here. The short form and lowercase characters are used as a reminder that both forms are allowed.
Explanation	Additional explanations and hints.

Command Set

SYSTem Subsystem

SYSTem:RESet

Use Initiates a software RESET. All set Parameter in the instrument are re-set to their default values. Error queue is cleared.

Example

```
💻→ SYST:RES
💻→ System:reset
```

Explanation The RESET command initializes the complete instrument including the IEEE interface. Commands, that are in the command buffer, or those which are entered shortly after the RESET, may be deleted by the RESET command and are therefore not executed.

SYSTem:ERRors?

Use Queries the number and types of errors since the last Query ¦ Startup ¦ System:Reset command.

Answer <Error_No> *integer*

Range

100 No subsystem separator found (':')
101 No subsystem found
102 No command separator found (':')
110 No SYSTem command found (e.g. RESET)
120 No INPut command found (e.g. LINK)
121 No INPut[1-2] command found (e.g. RANGE)
130 No OUTPut command found (e.g. FLOAT)
131 No OUTPut[1-2] command found (e.g. LEVEL)
132 No MTONe command found (e.g. START)
133 No TRIGger command found (e.g. ARMed)
140 No MEASurement command found (e.g. LEVEL)
141 No MEASurement[1-2] command found (e.g. TDN)
145 No device status command found (e.g. *OPC)
149 TRIGger configuration parameter expected (e.g. LOOSE)
150 No parameter expected
151 Float parameter expected
152 Float parameter out of range (e.g. INP:RANG -5E3)
153 Integer parameter expected
154 Integer parameter out of range
155 String parameter expected (e.g. "ON")
156 "ON" or "OFF" string expected
157 Filter parameter expected (e.g. "CCITT")
158 Location parameter expected (e.g. "FRONT")
159 Sync parameter expected (e.g. "EXTERNAL")
160 String too long
161 Wrong number of samples (512,1024,2048,4096,8192)
162 Corresponding frequency to bin number out of range
163 Phase value out of range
164 Wrong number of MT Parameter
165 IEEE bus error
166 Output buffer overflow

167 Bins must be in increasing order
168 Too many parameter
169 Integer parameter must be in increasing order
170 Illegal unit
180 Option not installed (e.g. FLOAT)
182 Command not executable during input trigger armed mode
190 Not available in this hardware version
191 Not available with this firmware version
199 Unexpected error occurred – please report to NEUTRIK
200 No parameter in list for start multitone signal in generator
201 No parameter in list referring to received data in analyzer
202 Output 1&2 muted while multitone is started
203 No trigger detected
204 No stereo trigger detected (e.g. for phase measurement)
205 Measurement function needs ≥1 identical bins on both channels
206 Measurement function needs ≥1 different bins on both channels
210 Analyzer overload
220 Battery low (memory backup)
230 Hardware and software revisions do not match
240 Minimum one external measurement required beforehand
246 Measurement not possible – Signal bins defined too close to each other (chose higher block length or change signal bins)
250 DTMF receive buffer overflow
255 RS232/GPIB Interface Output Buffer overflow
256 RS232/GPIB Interface Input Buffer overflow
600-716 Please report to NEUTRIK

Example

```
💻 →    System:Errors?
→ 💻    130,203,204

💻 →    SYST:ERR?
→ 💻    0
```

Explanation If no errors occurred, a "0" is returned. In any other case the list of error numbers in the queue is returned. All errors are cleared in the instrument after the query.

SYSTem:INFormation?

Use Query for serial number, hardware revision and firmware version of RT-1M system. Compatible with SCPI <*IDN?> command.

Answer

<Manufacturer>	*string*
<Instrument_type>	*string*
<Serial_number>	*string* (4 digits)
<Firmware_Revision>	*float*

Example

```
💻 →    System:Information?
→ 💻    NEUTRIK,RT1M,0456,3.20
```

INPut Subsystem

INPut:FRONt [ON¦OFF]

Use Activates either front or rear panel input connectors (output connectors are always active at front & rear panel).

Range OFF ¦ ON *boolean*

Default ON (front input connectors are active)

Query Use command ***INPut[1-2]:STATus?***

Example 💻 → `Inp:Fron OFF`

INPut[1-2]:LINK [OFF¦ON]

Use Links internally the generator output of RT-1M to the analyzer input. The input connectors of the selected channel are physically disconnected at front and rear.

Range OFF ¦ ON *boolean*

Default OFF

Query Use command ***INPut[1-2]:STATus?***

Example 💻 → `Input2:Link ON`

💻 → `INP1:LINK OFF`

Explanation This command allows e.g. to check the proper operation of RT-1M.

INPut[1-2]:RANGe <Range> <Unit>

Use Defines the input range & unit for an input channel.

Parameter <Range> *float*
<Unit> *string*

Unit [dBVp ¦ Vp]

Range -60 to +20 dBVp (rounded to nearest 0.1dBV)
0.001 to 10 Vp

Default 0 dBVp

Query Use command ***INPut[1-2]:STATus?***

Example 💻 → `INPUT1:Range 0 dBVp`

💻 → `Inp2:Rang 0.5 Vp`

Explanation Insert a white space between the value and the unit. The allowed units are peak level units only, since the Crest factor of the input signal is unknown.

INPut:SYNC [INTernal¦INTNoheader¦EXTernal¦EXTNoheader]

Use Defines the synchronization mode of the instrument.

Range INT ¦ INTN ¦ EXT ¦ EXTN *boolean*

INT Analyzer sampling clock is derived from the generator crystal. No frequency shift correction is performed. Use this mode if analyzer and generator are located together and no frequency shifts are expected. Max. allowable time delay is 1s.

INTN Analyzer sampling clock is derived from the generator crystal. No frequency shift during transmission must occur. The multitone signal is sent out without any header. The analyzer expects the multitone signal without trigger and SYNC block. Use this mode if analyzer and generator are located together but no header information can be transmitted (e.g. muted measurements) or for analysis of externally generated signals. Max. allowable time delay is 50ms.

EXT The analyzer clock is synchronized to the frequency of the SYNC block in the header of the received multitone burst. Frequency shifts are compensated. This mode is recommended if notable frequency shifts are expected. Max. allowable time delay is 1s.

EXTN No synchronization is transmitted or performed at all. Analyzer clock runs at the frequency synchronized to the last transmitted multitone burst in Sync Mode EXT. No further tuning will be performed. Analyzer expects the signal with no trigger information and generator is set to transmit the multitone signal only. No major time delay must occur in that mode. This mode requires at least one measurement in EXT mode before to ensure that the analyzer crystal is tuned.

Default INT

Query Use command ***INPut[1-2]:STATus?***

Example 💻 → `Inp:Sync Internal`

💻 → `INPUT:SYNC INTN`

Explanation Any multitone burst transmission & sampling must be initiated by ***OUTPut:MTONe:STARt***.

INPut:SWFilter [OFF¦CWE¦CCITT]

Use Activates one of the implemented software weighting filters. Filters are selected for both channels simultaneously. The filters may be engaged also after the measurements has been performed. This allows to get first unweighted and afterwards weighted results.

Range OFF ¦ CWE ¦ CCITT *boolean*

Default OFF

Query Use command ***INPut[1-2]:STATus?***

Example 💻 → `INPUT:SWFILTER OFF`

💻 → `Inp:SWF CWE`

INPut:DEEMphasis [OFF¦ON]

Use Activates the 750µs deemphasis, which applies on both channels, regardless of other filters.

Range OFF ¦ ON *boolean*

Default OFF

Query Use command ***INPut[1-2]:STATus?***

Example 💻→ `INP:DEEM ON`

💻→ `Input:Deemphasis OFF`

INPut:TRIGger:ARMed

Use Puts RT-1M into the armed mode, where the analyzer waits for an externally generated incoming multitone burst with trigger.

Query Use commands ***INPut:TRIGger:ARMed?*** and ***INPut[1-2]:STATus?***

Example 💻→ `Inp:Trigger:Armed`

Explanation This command allows the analyzer to receive multitone bursts that have been generated by a remote RT-1M unit, i.e. to run the analyzer in the so-called ***Broadcast Mode***.
In the armed status, the Trigger LED will be flashing until a trigger is detected (LED is lit).

Keep in mind that for broadcast applications it is necessary to set the synchronization mode of the generator / analyzer to INTernal / EXTernal, while the trigger configuration for both units must be TIGHT (see p. ***3-36***).

INPut:TRIGger:ARMed?

Use Queries whether RT-1M is in the armed mode.

Answer <Trigger_Status>

Range ARMED ¦ STOPPED *string*

ARMED — As long as RT-1M is in this mode, it will wait until an incoming multitone burst is detected or until the unit is re-set into the normal operation.

STOPPED — This status indicates that RT-1M is not armed (i.e. waiting for a trigger), but in the normal mode. In this status, the Trigger LED will be dark.

Example 💻→ `Inp:Trigger:Armed?`
→💻 ARMED

INPut:TRIGger:BREak

Use Disables the armed mode of RT-1M, i.e. re-sets the unit into the normal mode.

Query Use commands *INPut:TRIGger:ARMed?* and *INPut[1-2]:STATus?*

Example 🖳 → `Inp:Trigger:Break`

Explanation This command returns RT-1M into the normal operation, after it has been in the armed mode.
In the normal mode, the Trigger LED will be dark.

INPut:TRIGger:CONFiguration [LOOSE¦TIGHT¦USER]

Use Sets the trigger configuration.

Range LOOSE ¦ TIGHT ¦ USER *string*

LOOSE Applies the normal trigger condition on an incoming multitone burst. This configuration is especially suited for industrial applications, where both multitone generator and analyzer are located in the same housing.

TIGHT Applies the tight trigger condition on an incoming multitone burst. This configuration should be used for broadcast applications, where the signal is inserted into a shortly interrupted broadcast signal.

USER This configuration allows the user to define the trigger condition individually. However, since this requires a highly sophisticated fine-tuning, it is strongly recommended to be used by very advanced users only.

Default LOOSE

Query Use command *INPut[1-2]:STATus?*

Example 🖳 → `Inp:Trigger:Configuration Tight`

Explanation It is recommended to change the trigger configuration for broadcast operation only, and to select the TIGHT condition in such cases. As soon as RT-1M is used again for industrial applications, the trigger configuration should be re-set to LOOSE.

INPut:TRIGger:USRConfiguration <setbin1(dB)>,<setbin2(dB)>,<emptybin(dB)>

Use Allows to custom-design the trigger configuration by defining the trigger bins.

Parameter

<setbin(1)>	*integer*
<setbin(2)>	*integer*
<emptybin>	*integer*

Range

<setbin(1)>	-10 to -50 dB
<setbin(2)>	-10 to -50 dB
<emptybin>	0 to -80 dB

Query Use command *INPut:TRIGger:USRConfiguration?*

Example 💻→ `Inp:Trigger:Usrconfiguration -20,-40,-80`

Explanation

This command requires highly sophisticated handling for proper operation! It shall not be applied as by very advanced users only!

INPut:TRIGger:USRConfiguration?

Use Queries the defined trigger configuration.

Answer

<setbin1>	*integer*
<setbin2>	*integer*
<emptybin>	*integer*

Range

<setbin1>	-10 to -50 dB
<setbin2>	-10 to -50 dB
<emptybin>	0 to -80 dB

Example

💻→ `Inp:Trigger:Usrconfiguration?`
→💻 `-20,-40,-80`

Explanation See chapter ***Broadcast Mode***.

INPut[1-2]:STATus?

Use Queries the complete input channel status.

Answer

<Range_Unit>	*float & string*	RANGE [-60 to +20 dBVp ¦ 0.001 to 10 Vp]
<SW_Filter>	*boolean*	SWFILTER [OFF ¦ CWEighting ¦ CCIT]
<Front_Conn>	*boolean*	FRONT [OFF ¦ ON]
<Link>	*boolean*	LINK [OFF ¦ ON]
<SYNC_Mode>	*boolean*	SYNC [INT ¦ INTN ¦ EXT ¦ EXTN]
<Deemphasis>	*boolean*	DEEMPHASIS [OFF ¦ ON]
<Trig_Config>	*string*	TRIGGER [LOOSE ¦ TIGHT ¦ USER]

Example

💻→ `Inp2:Status?`
→💻
```
RANGE -3.5000E0 dBVp,SWFILTER CCITT,FRONT OFF,
LINK ON,SYNC INTERNAL,DEEMPHASIS ON,TRIGGER:
CONFIGURATION LOOSE
```

💻→ `INPUT1:STAT?`
→💻
```
RANGE 1.0000E1 Vp,SWFILTER OFF,FRONT ON,LINK
OFF,SYNC EXTERNAL,DEEMPHASIS ON,TRIGGER:
CONFIGURATION TIGHT
```

OUTPut Subsystem

OUTPut:MTONe:PARameter <Parameter>

Use Defines a multitone signal.

Parameter

<Sig_Number>	*integer*	target memory of RT-1M
<Sig_Name>	*string*	user-defined signal name
<No_Of_Samples>	*integer*	blocklength
<No_Of_Bins_CH1>	*integer*	total number of bins set in channel 1
<No_Of_Bins_CH2>	*integer*	total number of bins set in channel 2
{<Bin_X_CH1>}	*integer*	bin numbers set in Chn1
{<Bin_X_CH2>}	*integer*	bin numbers set in Chn2
{<Phase_X_CH1>}	*float*	phases of bins set in Chn 1
{<Phase_X_CH2>}	*float*	phases of bins set in Chn 2

Range

<Sig_Number>	1 ¦ 2 ¦ 3 ¦ 4
<Sig_Number>	(up to 8 ASCII characters, no spaces allowed)
<No_Of_Samples>	512 ¦ 1024 ¦ 2048 ¦ 4096 ¦ 8192
<No_Of_Bins_CH1>	1 to 31
<No_Of_Bins_CH2>	1 to 31
<Bin_No_X_CH1>	Bin_Min[1] to Bin_Max[2]
<Bin_No_X_CH2>	Bin_Min[1] to Bin_Max[2]
<Phase_X_CH1>	-π to +π
<Phase_X_CH2>	-π to +π

$$^{1)}\ Bin_Min = \left| \frac{NoOfSamples}{48'000\,Hz} * 20Hz \right| \qquad ^{2)}\ Bin_Max = \left| \frac{NoOfSamples}{48'000\,Hz} * 20kHz \right|$$

Query Use command ***OUTPut:MTONe:PARameter?***

Example 🖳 →

```
Output:Mtone:Par
1,'Telefon',2048,3,3,25,85,256,25,85,256,0,1.5707
,3.14,0,1.5707,3.1415
```

Explanation This command defines all compulsory parameter of a new multitone signal.
<No_Of_Bins_CH*X*> equals the total number of signal bins for channel 1 / 2.
<Bin_No_X_CH*Y*> indicate the bin numbers as calculated with *Equation 7* (p. 25).
<Phase_X_CH*Y*> indicate the phases of the signal bins.

OUTPut[1-2]:LEVel <Level> <Unit>

Use Set the total output level of the multitone signal.

Parameter

<Level>	*float*
<Unit>	*string*

Unit dBVp ¦ Vp ¦ dBV ¦ V

V	Peak value in logarithmic scale (RMS value is lower by crest factor)
dBV	Peak value in linear scale (RMS value is lower by crest factor)
Vp	RMS output level in logarithmic scale (peak level is higher by crest factor)
dBVp	RMS output level in linear scale (peak level is higher by crest factor)

Range

-60 to +20	dBVp	(rounded to nearest 0.1dBVp)
+0.001 to +10	Vp	

Default 0 dBVp

Query Use command ***OUTPut[1-2]:STATus?***

Example 💻→ `Outp1:Level -6.2 dBVp`

💻→ `OUTPUT2:LEVEL 3.5 V`

Explanation This command allows to set the output level in either RMS or peak units. The maximum output level of 10Vp cannot be exceeded..

OUTPut:MTONe:PRETriggerlength <Length>

Use Definition of the pretrigger duration for the active multitone signal in milliseconds.

Parameter <Length> *float*

Range 0 to 30'000

Unit ms (milliseconds)

Default 0

Query Not possible.

Example 💻→ `Output:Mtone:Pret 0`

💻→ `Outp:Mtone:Pretriggerlength 50.5`

Explanation The duration value is rounded to the next possible value. The duration of the pretrigger excludes the duration of the trigger, which always occupies some 42ms. The value 0 defines the shortest possible pretrigger length of 0ms.
The command mainly allows the DUT to stabilize before the multitone signal is transmitted.

OUTPut:MTONe:MTONelength <Length>

Use Definition of the multitone signal duration for the active multitone signal in milliseconds.

Parameter <Length> *float*

Range 0 to 30'000

Unit ms (milliseconds)

Default 0

Query Not possible

Example 💻→ `Output:Mtone:Mton 500`

Explanation The duration value is rounded to the next possible integer multiple of the duration of one multitone block. The value 0 results in transmission of the min. number of multitone blocks. The command mainly allows the DUT to stabilize onto the multitone signal before analysis is started.

OUTPut[1-2]:BINlevel <Level> <Unit>

Use Set the bin level of the multitone signal (all bins have equal level).

Parameter
<Level> *float*
<Unit> *string*

Unit dBV ¦BV ¦ dBVp ¦ Vp
dBV RMS binlevel in linear scale
V RMS binlevel in logarithmic scale
dBVp Peak value in linear scale
Vp Peak value in logarithmic scale

Range -60 to xx dBVp (max. binlevel has to be calculated acc. ***Equation 1*** & ***Equation 6***)
+0.001 to +yy Vp

Query Use command ***OUTPut[1-2]:STATus?***

Example 💻 → `Outp1:Binlevel -6.2 dBVp`

Explanation

> **Be aware that when bin level is set, the total output level is higher as per *Equation 6*. The maximum output level of 10Vp cannot be exceeded.**

OUTPut[1-2]:MUTe [OFF¦ON]

Use Mute or unmute a channel output.

Range OFF ¦ ON *boolean*

Default OFF

Query Use command ***OUTPut[1-2]:STATus?***

Example 💻 → `Output1:Mute ON`

💻 → `OUTP1:MUT OFF`

OUTPut:FLOAT [OFF¦ON]

Use Sets both output channels to either float or ground mode. In float mode the center tap of the generator can float to any level. Ground mode is necessary for unbalanced output signals.

Range OFF ¦ ON *boolean*

Default OFF

Query Use command ***OUTPut[1-2]:STATus?***

Example 💻 → `Output:Float ON`

OUTPut:MTONe:ACTive [1¦2¦3¦4]

Use Defines the current multitone signal as the active signal used for transmission. All commands with no signal number refer to the active signal.

Range 1 ¦ 2 ¦ 3 ¦ 4 *integer*

Default 1

Query Use command ***OUTPut[1-2]:STATus?***

Example 💻 → `OUTP:MTON:ACT 2`

💻 → `Output:Mtone:Active 1`

OUTPut:MTONe:STARt

Use Start transmission (i.e. generation & analysis) of the active multitone burst.

Example 💻 → OUTP:MTONE:START

Explanation This command has to be sent either if a multitone burst shall be
- generated and analyzed *or*
- generated only *or*
- sampled & analyzed only.

OUTPut:MTONe:CONtinuous

Use Starts the generator to endlessly send out the active multitone signal.

Example 💻 → `OUTP:MTONE:CON`

Explanation The signal is sent out in an endless loop. Only the multitone signal is transmitted, i.e. without header. **No measurement may be performed on this signal.** This is a generation mode only. The signal can be stopped by any IEEE command being sent to RT-1M.

OUTPut[1-2]:STATus?

Use Queries the generator status for channel 1 or channel 2.

Answer

<Active>	*string*	ACTIVE [1 ¦ 2 ¦ 3 ¦ 4]
<Out_Level>	*string*	LEVEL [-60 to +20 dBVp ¦ 0.001 to 10 Vp]
<BinLevel>	*string*	BINLEVEL [-60 to xx dBVp ¦ 0.001 to yy Vp]
<Mute_State>	*boolean*	MUTE [ON ¦ OFF]
<Float_State>	*boolean*	FLOAT [ON ¦ OFF]

Resolution <Out_Level> 0.1dBV

Example

💻 → `OUTPUT1:STATUS?`

→ 💻 `ACTIVE 1,LEVEL -3.5000E0 dBV,BINLEVEL 0.1 V,`
`MUTE OFF,FLOAT ON`

OUTPut:MTONe:NAME?

Use Queries the name of the active multitone signal.

Answer <Name> *string*

Default (the active signal name)

Example
```
💻 →   Output:mtone:Name?
→ 💻   Telephon
```

OUTPut:MTONe:BLOCklength?

Use Queries the number of samples (i.e. blocklength) of the active multitone signal.

Answer <Blocklength> *integer*

Range 512 ¦ 1024 ¦ 2048 ¦ 4096 ¦ 8192

Example
```
💻 →   OUTput:MTONe:BLOCklength
→ 💻   2048
```

OUTPut:MTONe:PARameter?

Use Queries the parameter of the active multitone signal. Format is compatible with the command ***OUTPut:MTONe:PARameter***.

Answer

<Sig_Number>	*integer*	1 ¦ 2 ¦ 3 ¦ 4
<Sig_Name>	*string*	up to 8 ASCII characters
<No_Samples>	*integer*	512 ¦ 1024 ¦ 2048 ¦ 4096 ¦ 8192
<No_Of_Bins_CH1>	*integer*	1 to 31
<No_Of_Bins_CH2>	*integer*	1 to 31
{<Bin_X_CH1>}	*integer*	Bin_Min to Bin_Max
{<Bin_X_CH2>}	*integer*	Bin_Min to Bin_Max
{<Phase_X_CH1>}	*float*	-π to +π
{<Phase_X_CH2>}	*float*	-π to +π

Example
```
💻 →   Output:Mtone:Par?
→ 💻   1,Telefon,2048,3,2,25,85,256,11,102,0.000E+00,1.5
       707E+00,3.14150E+00,1.234E+00,0.14170E+00
```

OUTPut[1-2]:MTONe:CRESt?

Use Queries the Crest factor of the active multitone signal.

Answer <Crestfac> *float*

Range (any positive number ≥√2)

Example
```
💻 →    OUTP1:MTONe:CREST?
→ 💻    2.33433E0
```

Explanation Refer to chapter ***Phase / Crest Factor Optimization*** for further explanations.

MEASurement Subsystem

MEASurement[1-2]:LEVel:UNIT [dBVp¦Vp¦dBV¦V]

Use Defines the unit in which the level results shall be expressed.

Range dBVp ¦ Vp ¦ dBV ¦ V *string*

Default dBVp

Example 💻 → `MEAS1:LEV:UNIT VP`

MEASurement[1-2]:LEVel?

Use Returns the measured signal bin levels of the last received multitone signal for one channel.

Answer

{Set_bin_n}	*integer*	
{Amplitude_n}	*float & string*	(level value & unit)

Range

Set_Bin_n	Bin_Min to Bin_Max (see ***Equation 4*** and ***Equation 5***)
Amplitude_n	*float* ¦ NaN & *string*

Unit Defined by ***MEASurement[1-2]:LEVel:UNIT [dBVp¦Vp¦dBV¦V]***.

Default NaN (not a number)

Example

💻 → `MEAS1:LEV?`

→ 💻 `3/1.240E0 dBV,23/9.727E-1 dBV,84/8.254E-1 dBV`

Explanation The returned level vector is grouped in result pairs, starting with the first signal bin number, a "/", the corresponding level value, a white space, and the unit, in which the result is expressed. Pairs are separated by commas.
If a received level is too low to be measured, 'NaN' (not a number) is returned.

MEASurement[1-2]:DISTortion:UNIT [dBV¦V]

Use Defines the unit in which the distortion result shall be expressed.

Range dBV ¦ V *string*

Default dBV

Example 💻 → `MEAS1:DIST:UNIT V`

MEASurement[1-2]:DISTortion?

Use Returns the distortion values of all the bands between Bin_Min → Bin_1, Bin_1 → Bin_2, etc., Bin_n → Bin_Max (see also ***Distortion***).

Answer

Bin_Min	*integer*
Dist_1	*float + string*
{Set_bin_n}	*integer*

	{Dist_n}	*float* + *string*
Range	Bin_Min	Bin_Min
	{Set_Bin_n}	Bin_Min to Bin_Max (see ***Equation 4*** and ***Equation 5***)
	Dist_1,{Dist_n}	*float* ¦ NaN + *string*

Unit Defined in ***MEASurement[1-2]:DISTortion:UNIT***

Example
```
💻 →   Measurement1:Dist?
→ 💻   3/2.23E-2 V,11/8.23E-3 V,27/1.35E-2 V
```

Explanation The returned distortion vector starts with the number of the first bin ≥20Hz / the distortion up to the first signal bin. Second pair is the number of the first signal bin / the distortion result between this first signal bin and the second signal bin, etc. The last pair is the last signal bin / the distortion result between this last signal bin and Bin_Max (last bin ≤20kHz; see ***Fig. 20***). If a band between two signal bins is too narrow to measure a distortion, 'NaN' is returned.

MEASurement[1¦2]:MTSinad?

Use Returns the SINAD value using the selected Multitone signal in the full bandwidth between Bin_Min (>20Hz) and Bin_Max (<20kHz). The single value calculation considers: Signal plus Distortion plus Noise to Distortion plus Noise for any defined multitone signal. (see also chapter ***MT-SINAD, p. 30***).

Answer	Bin_Max/	*integer*	(see ***Equation 5, p. 19***)
	MT_Sinad	*float* ¦ NaN & *string*	(measured MT-SINAD result & unit)

Default NaN (not a number)

Unit dB

Example
```
💻 →   Measurement1:MTSinad?
→ 💻   214/5.2235E+01 dB
```

Explanation The returned MT-SINAD value considers all signal components, starting with the lowest possible frequency in the signal at the first bin ≥20Hz up to the highest frequency bin below 20kHz. It calculates from the distortions and the signal components the single SINAD value. If a band between two signal bins is too narrow to measure a distortion, the error 246 is returned.

MEASurement[1-2]:SELectiverss:UNIT [dBV¦V]

Use Defines the unit in which the RSS (root sum square) selective result shall be expressed.

Range	dBV ¦ V	*string*
Default	dBV	

Example
```
💻 →   Meas1:Sel:Unit dBV
```

MEASurement[1-2]:SELectiverss? <binstart> <binstop>

Use Returns the RSS value for the band from <binstart> to <binstop> (including both levels).

Parameter <binstart>, <binstop> *integer*

Range Bin_Min to Bin_Max

Units Defined by

MEASurement[1-2]:SELectiverss:UNIT [dBV¦V].

Default NaN (not a number)

Example

```
💻 →   MEAS2:SEL? 11 32
→ 💻   32/-1.01352169+02 dBV
```

(RSS value from Bin #11 to Bin #32, including levels of Bin #11 + #32)

Explanation The RSS selective measurement (see p. ***3-30***) allows to measure the total distortion + noise in any frequency band between 20Hz - 20kHz. <binstart> defines the lower border of this band, while <binstop> defines the upper border of the band.
Please notice, that if the selected band comprises a signal bin, the RSS selective result will include this signal bin level in addition to the distortion + noise value of the band.

MEASurement[1-2]:NOISe:UNIT [dBV¦V]

Use Defines the unit in which the noise measurement results shall be expressed.

Range dBV ¦ V *string*

Default DBV

Example

```
💻 →   MEAS1:NOISE:UNIT V
```

MEASurement[1-2]:NOISe?

Use Returns the noise values of all the bands between 20Hz → Bin_Min, Bin_Min → SigBin_1, etc., SigBin_n → Bin_Max, Bin_Max → 20kHz (see also chapter ***Noise***).

Answer

Bin_Min	*Integer*
Noise_1	*float + string*
{SigBin_n}	*integer*
{Noise_n}	*float + string*

Range

Bin_Min	Bin_Min
{Set_Bin_n}	Bin_Min to Bin_Max (see ***Equation 4*** and ***Equation 5***)
Noise_1,{Noise_n}	*float* ¦ NaN + *string*

Unit As defined by command ***MEASurement[1-2]:NOISe:UNIT [dBV¦V]***

Default NaN (not a number)

Example

```
💻 →   Measurement1:Noise?
→ 💻   3/6.56E-3 V,11/7.32E-3 V,27/6.55E-3 V,
       87/5.87E-3 V,2048/4.27E-3 V
```

Explanation The returned noise vector starts with Bin_Min (i.e. the first possible bin ≥20 Hz), followed by the noise result between this bin and the first signal bin. Second pair is the bin number of the first signal bin and the noise value between this first signal bin and the second signal bin, etc. Last pair is the last signal bin with the noise result between the last signal bin and Bin_Max (i.e. the last possible bin ≤20kHz). See also ***Fig. 22***.
If a band between two signal bins is too narrow to measure noise value, 'NaN' is returned.

MEASurement[1-2]:CROSstalk:UNIT [dB¦%]

Use Defines the unit in which the crosstalk measurement shall be expressed.

Range dB ¦ % *string*

Default %

Example 💻 → `MEAS1:CROS:UNIT dB`

MEASurement[1-2]:CROSstalk?

Use Returns the measured crosstalk of the last received multitone signal for one channel. The crosstalk result can be evaluated only if at least one signal bin of each channel is set at an exclusive frequency.

Default NaN (not a number)

Example
💻 → `MEAS1:CROS?`
→ 💻 `3/-87 dB,11/-67 dB`

Explanation The returned result pairs indicate the signal bin number, followed by a "/", the corresponding crosstalk value, a white space, the unit, in which the result is expressed, and a ",".
If the crosstalk value is too small to be measured, 'NaN' (not a number) will be returned.

MEASurement:PHASe:UNIT [rad¦deg]

Use Defines the unit in which the phase measurement result shall be expressed.

Range rad ¦ deg *string*

Default rad

Example 💻 → `MEAS:PHASE:UNIT DEG`

MEASurement:PHASe:SCALe <Scale>

Use Defines the lower border of the phase-plot scale, in which the result shall be expressed. The scale always comprises a full circle, i.e. 2π (rad) or 360° (deg) respectively.

Parameter <Scale> *float*

Range [-2π to 0 ¦ –360 to 0]

Default 0

Example 💻 → `MEAS:PHASE:SCALE -180` (-180 to +180 deg.)

💻 → `Meas:Phas:Scal 0` (0 to +2π rad.)

MEASurement[1-2]:PHASe?

Use Returns the measured phase-difference between the 2 channels of the last received multitone signal. The phase value can be calculated only if both channels have recognized a trigger and if at least one signal bin is identical, i.e. set on both channels.
ATTENTION: In order to get accurate phase values, it is important to set the input ranges of both channels to the same level.

Answer

{SigBin_1}	*integer*
{Phase_1}	*float* + *string*
{SigBin_n}	*integer*
{Phase_n}	*float* + *string*

Range

{SigBin_n}	Bin_Min to Bin_Max (see ***Equation 4*** and ***Equation 5***)
{Phase_n}	*float* ¦ NaN + *string*

Unit (as defined by command ***MEASurement:PHASe:UNIT***)

Example 💻 → `MEAS1:PHASE?`
→ 💻 `3/1.24E0 deg,23/9.27E-1 deg`

Explanation The returned result is composed of pairs, each starting with the signal bin number, followed by a "/", the phase result, a white space the unit, in which the phase was measured, and a ",".

MEASurement1:DTMF:STARt

Usage Resets the DTMF tone receiver buffer (32 keys wide) of channel 1.
NOTE: This command requires installation of the DTMF option for RT-1M.

Examples 💻 → `Meas1:Dtmf:Start`

Explanation After this command, RT-1M continues to store all incoming DTMF tones in its buffer.

MEASurement1:DTMF?

Usage Queries the DTMF tone receiver buffer (32 keys wide) of channel 1.
NOTE: This command requires installation of the DTMF option for RT-1M.

Examples 💻 → `MEAS1:DTMF?`
→ 💻 `1/2,2/3,2/2` (3 keys detected: 2,8,5)

Explanation RT-1M returns pairs of x-/y-coordinates, identifying the DTMF keys in the received order.
The standard 4x4 keypad coding is:
(unused fields may be user-defined)

↓*y-coord.*	*1*	*2*	*3*	*4* → *x-coord.*
1	1	2	3	A
2	4	5	6	B
3	7	8	9	C
4	*	0	#	D

Device Status

*STB?

Use Fetches the STatus Byte register. See also chapter ***IEEE Standard Status Data Structure***.

Calculation $STB = n_7*128 + n_6*64 + n_5*32 + n_4*16 + n_3*8 + n_2*4 + n_1*2 + n_0$

n_7	Not used
n_6	Master summary status (MSS) The MSS message indicates that RT-1M has at least one reason for requesting service.
n_5	Event status summary bit (ESB), indicating whether any of the enabled events has occurred since the last reading of the standard event status register.
n_4	Message available summary bit (MAV). The MAV message indicates whether or not the output queue is empty. Whenever RT-1M is ready to accept a request by the controller to output data, MAV summary message will be TRUE.
n_3	Not used
n_2	Not used
n_1	Not used
n_0	Not used

Example

```
💻 →   *STB?
→ 💻   32
```

*OPC

Use The OPeration Complete command causes RT-1M to generate the operation complete message in the standard event status register (Bit 0) when all pending selected device operations have been finished. The *OPC command allows synchronization between controller and RT-1M..

Example

```
💻 →   *esr?                          (clears previous events)
       *ese 1;*sre 32                 (enable operation complete event)
       output:mtone:start, *OPC       (RT-1M will request service [serial poll]
                                       as soon as the measurement is finished)
```

*OPC?

Use The OPeration Complete query causes RT-1M to place an '1' into the RT-1M output queue when all pending selected device operations have been finished. The *OPC command allows synchronization between controller and RT-1M using the MAV bit in the status byte register. See also chapter ***IEEE Standard Status Data Structure***.

Parameter <OPCvalue> *boolean*

Range

0	not finished
1	finished

Example

```
💻 →   *OPC?
→ 💻   1
```

Explanation Use *OPC? with serial polling (e.g. MAV).

*CLS

Use The CLear Status command clears status data structures, i.e. standard event status registers, so that the corresponding summary ESB bit is clear. See also chapter ***IEEE Standard Status Data Structure***.

Example 💻 → `*CLS`

Explanation *CLS has same effect as *ESR? query, except it is a command.

*ESE

Use The standard Event Status Enable command sets the standard event status enable register bits. The standard event status enable register allows one or more events in the standard event status register to be reflected in the ESB summary-message bit. See also chapter ***IEEE Standard Status Data Structure***.

Parameter <Enable_value> Byte

Range 0 to 255

Example 💻 → `*ESE 32` (enables command error event)

*ESE?

Use The standard Event Status Enable query allows the programmer to determine the current contents of the standard event status enable register. See also chapter ***IEEE Standard Status Data Structure***.

Parameter <Enable_value> Byte

Range 0 to 255

Example 💻 → `*ESE?`
→ 💻 `32`

*SRE

Use The Service Request Enable command sets the service request enable register bits. The service request enabling allows a programmer to select which summary messages in the status Byte register may cause service request (SRQ). The programmer can select reasons to issue a service request by altering the contents of the service request enable register. See also chapter ***IEEE Standard Status Data Structure***.

Parameter <Enable_value> Byte

Range 0 to 255

Example 💻 → `*SRE 32` (enables standard event status bit [ESB])

*SRE?

Use The Service Request Enable query allows to determine the current contents of the service request enable register. See also chapter ***IEEE Standard Status Data Structure***.

Parameter <Enable_value> Byte

Range 0 to 255

Example
💻 → `*SRE?`
→ 💻 `32`

*ESR?

Use The standard Event Status Register query allows the programmer to determine the current contents of the standard event status register. *Reading* the standard event status register *clears* it. See also chapter ***IEEE Standard Status Data Structure***.

Calculation $ESR = n_7*128 + n_6*64 + n_5*32 + n_4*16 + n_3*8 + n_2*4 + n_1*2 + n_0$

n_7	Power-On event flag, indicating that an Off-to-On power transition has occurred
	Not used
n_6	Command error event flag, indicating that either a syntax or a semantic error has
n_5	been detected. The error-number can be read with the <system:errors?> query
	Not used
n_4	Device specific error event flag (e.g. no trigger detected). The occurred error-
n_3	number can be read with the <system:errors?> query.
	Not used
n_2	Not used
n_1	Operation complete event flag. This event bit is generated in response to the *OPC
n_0	command. It indicates that the device has completed all pending operations.

Parameter <Enable_value> Byte

Range 0 to 255

Example
💻 → `*ESR?`
→ 💻 `32` (command error has occurred)

*PSC

Use The Power-on Status Clear command controls the automatic power-on clearing of the service request enable register and the standard event status enable register.
<*PSC 0> no power-on clearing of the registers.
<*PSC 1> power-on clearing of the registers and therefore disabling of service request assertion after power-on
See also chapter ***IEEE Standard Status Data Structure***.

Parameter <Enable_value> Byte

Range 0 to 1

Default 0

Example 💻 → `*PSC 0`

*PSC?

Use The Power-on Status Clear query allows the programmer to query RT-1M's power-on status clear flag. See also chapter ***IEEE Standard Status Data Structure***
<*PSC 0> no power-on clearing of the registers.
<*PSC 1> power-on clearing of the registers and therefore disabling of service request assertion after power-on

Parameter <Power_on_flag> Byte

Range

0	not cleared
1	cleared

Example

💻 →	`*PSC?`
→ 💻	`0`

*IDN?

Use The IDentificatioN query gets the unique identification of RT-1M. See also chapter ***IEEE Standard Status Data Structure***.

Parameter

<Manufacturer>	*string*
<Instrument_type>	*string*
<Serial_number>	*string* [4]
<Firmware_revision>	*float*

Example

💻 →	`*IDN?`
→ 💻	`NEUTRIK,RT1M,0122,3.01`

*RST

Use The ReSeT command performs a device reset. All Parameter are set to default values except the output- and command-queue. See also chapter ***IEEE Standard Status Data Structure***.

Parameter No Parameter

Example

💻 →	`*RST`

*TST?

Use The self-TeST query causes an internal self-test and places a response into the output queue indicating whether or not RT-1M completed the self-test without errors.

Parameter <Self_test> Byte

Range

0	errors occurred
1	self test OK

Example

💻 →	`*TST?`
→ 💻	`1`

*WAI

Use The WAIt-to-continue command prevents RT-1M from executing any further commands or queries until the no-operation pending flag is TRUE. However, since RT-1M has implemented only sequential command execution, the no-operation command flag is always TRUE.

Example 💻→ `*WAI`

Examples

Use of an *OPC command

The *OPC and *WAI commands and the *OPC? query allow the controller to synchronize itself to the end of a calculation performed by *RT-1M*.

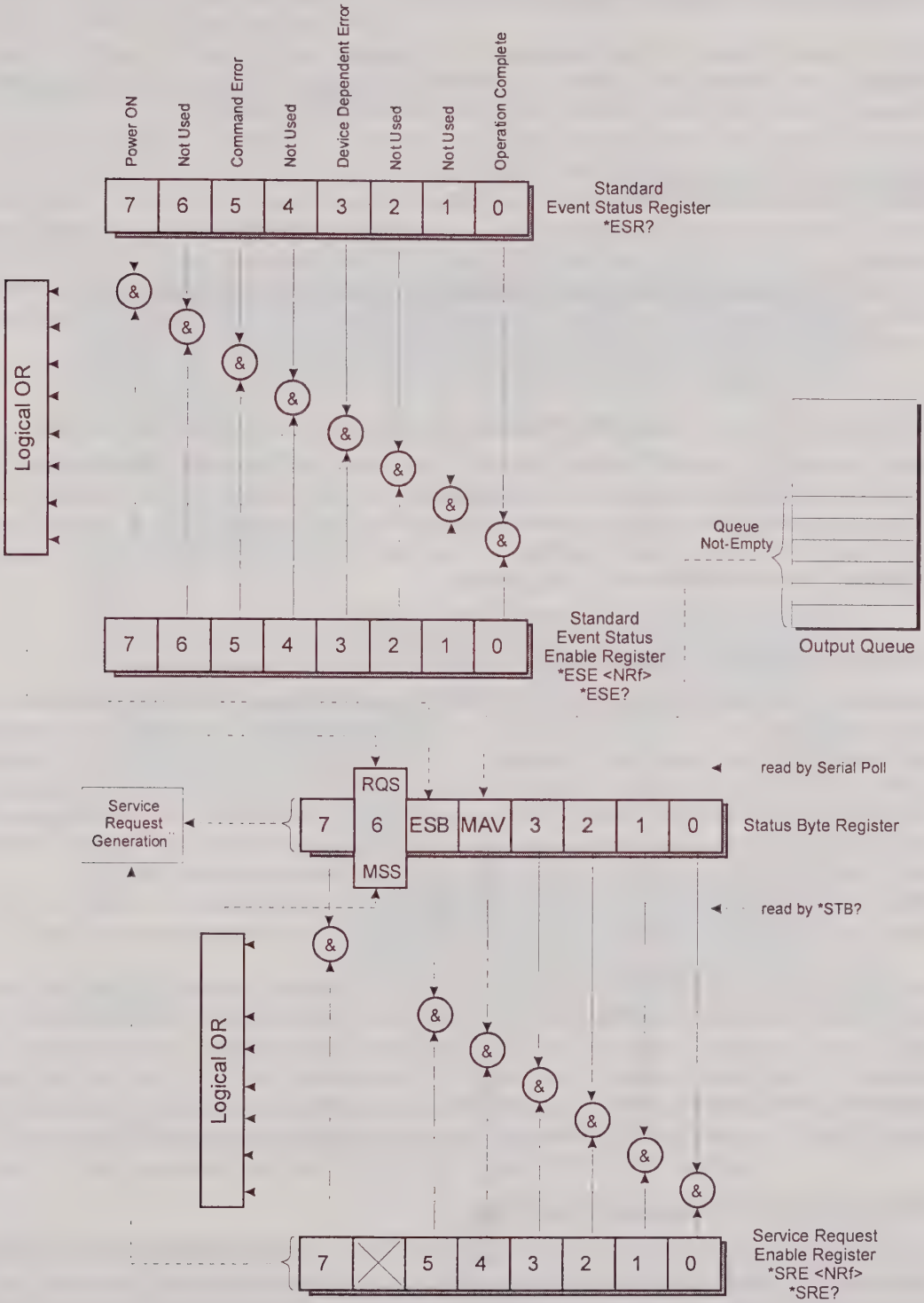
```
💻→ *esr?                                   (clears previous events)
    *sre 32;*ese 1                          (enable operation complete event)

    output:mtone:par
    1,'telephon',8192,3,3,600,1000,3000,
    630,970,3030,0,0,0,0,0,0,*opc

→💻                                         (as soon as the calculation is finished,
                                            RT-1M requests service [SRQ] by serially
                                            polling the controller)
```

Use of MAV bit in the status Byte register

```
💻→ *sre 16                 (enable Output queue Not-empty event)

    output:mtone:start      (start measurement)

    meas1:dist?             (get distortion values)

→💻                         (as soon as the output queue has the valid distortion results, RT-
                            1M requests service [SRQ] via serial poll)
```

As soon as e.g. a *SRE 16 has been sent to the unit, *RT-1M* is set to the service request mode. This means that *RT-1M* will send back a service request to the PC each time that it has a new message (e.g. measurement result) ready.
However, please notice that this message may be transferred to the PC by serial polling only, since *RT-1M* cannot add any further information to the service request.

IEEE Standard Status Data Structure



For more detailed information refer to IEEE Std 488.2-1992 (IEEE Standard Codes, Formats, Protocols, and Common Commands).

[1] Service Request clears RQS but not MSS!

5 Application Hints

RT-1M is ideally suited to be integrated into industrial environments, having virtually no switches and buttons. All control is established through IEEE commands, allowing to introduce Audio tests as a standard part of the entire QC procedure.

Arbitrary Generator

With its flexibility, ease of operation and its excellent price/performance ratio, RT-1M can be used as a simple arbitrary generator. This way, after few minutes of programming only, RT-1M can serve as a sine wave generator with one fixed, extremely stable frequency or as an IMD, DFD or W&F generator with two frequencies defined. The four dual channel memory locations also allow to have all these configurations permanently stored.

Alignment and Adjustments for Audio Repair Facilities

With the ability to plot two to three frequency responses every second, alignment sequences for tapes, where they have to be done manually, or bias adjustments of amplifiers can be speeded up. Repeated phase measurements simplify the alignment of the azimuth angle of the playback head of a tape recorder - a procedure that normally has to be repetitively performed for low-, mid- and high frequencies.

Cellular Phone Testing

Increasing production volume, based on the fast growth of cellular networks and coupled with the requirement for 100% testing of the units, makes an improvement at production bottleneck - the audio analysis - necessary. RT-1M is ideally suited to serve as a high-speed audio analyzer for production testing. The LF- output signal of the system may be RF-modulated and transmitted through an antenna, to quickly obtain the frequency response and distortion in the voice band of the whole signal path. Frequency shifts as they may appear on AM/FM transmissions are eliminated by the synchronization capabilities of RT-1M.
SINAD measurements with a single bin stimulus are possible down to a value of 1dB. The trigger detection works reliably if the signal is transmitted on the second channel, too.

The dual channel capabilities of RT-1M even makes it possible to perform transmit and receive testing simultaneously. One channel generates the source signal for the transmitter path of the phone (Mic input), while an external test demodulator feeds back the signal to the analyzer of the same channel. The output of the second channel is fed into an external modulator, that supplies the RF signal for the receiver path of the phone. The phone demodulates the signal and the feeds into the second analyzer channel of RT-1M.

Rub & Buzz Speaker Testing

The multitone feature of RT-1M is ideally suited for Rub & Buzz speaker testing in production lines. Most frequently seen defects of speakers are mechanical friction of the moving coil and the magnet, as well as excentrical alignments leading to a staggering movement of the coil. In any of these cases, the speaker either starts to produce nonlinear distortion or adds additional signal energy to frequencies not being part of the original signal. Both of these effects can be measured in a fraction of a second. Harmonics and new frequencies will appear in the distortion-, and in most cases in the noise-plot.

Anyway, the stimulation of a speaker with a multitone signal is more realistic and comes closer to real-world signals. Actually, the mentioned effects may remain unnoticed when stimulating with a single frequency only.

RT-EVAL Software Package

In order to simplify the operation of *RT-1M* especially for new users, an easy-to-understand evaluation package has been released. This versatile tool provides not only access to almost all available features of the unit, but also extends this range by some very useful functions like a Crest factor optimizer etc.

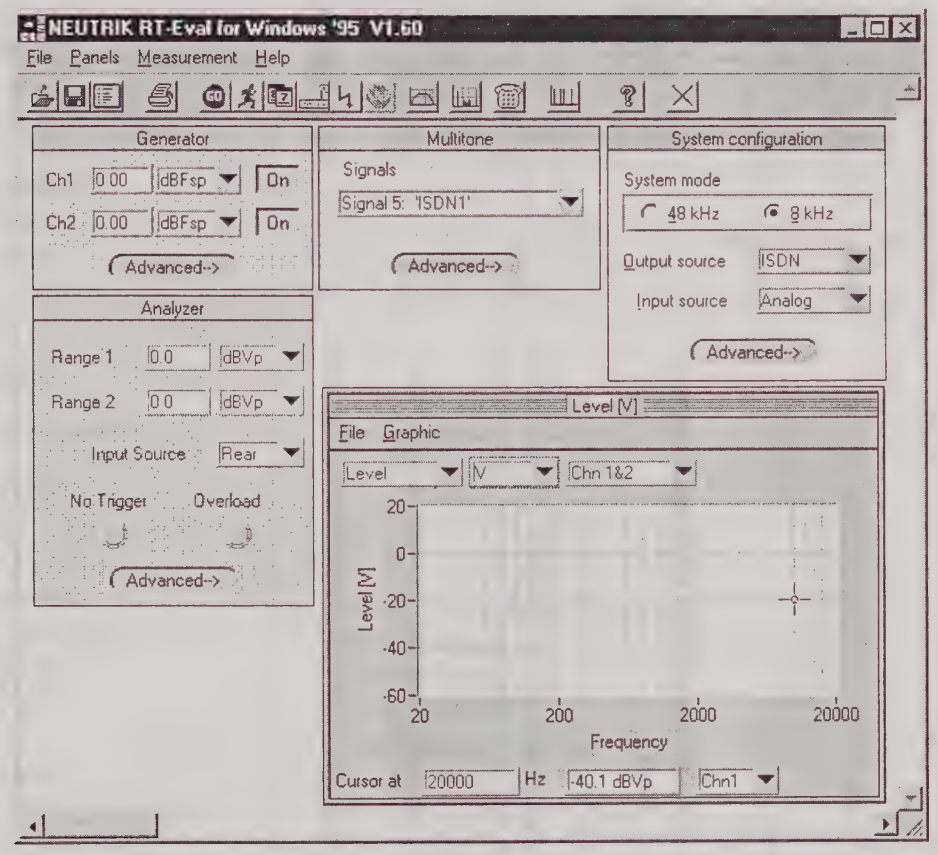


Fig. 25 RT-EVAL Screenshot

Fig. 25 shows a typical screen shot of the RT-EVAL software with generator, analyzer, multitone, system configuration & measurement panel.
Please contact you local representative to get a free copy of this package.

Units & Conversion

Especially in the field of telecommunication, there exists a large number of different units to express a level value, while for practical reasons, *RT-1M* provides a restricted number of these units only.
The subsequent table lists the most common units and provides the necessary conversion formulas and examples for a better understanding.

Unit	Explanation	Conversion Formulas
dB	Decibel - unit of measure of relative voltage level (U_1 measured against reference voltage U_2)	$dB = 20 * \log_{10}(\frac{U_1}{U_2})$
dBV	RMS Voltage in dB referred to 1[V_{RMS}]	$dBV = 20 * \log_{10}(\frac{U_{RMS}}{1[V_{RMS}]})$
dBVp	Peak Voltage in dB referred to 1[V_{Peak}]	$dBVp = 20 * \log_{10}(\frac{U_{Peak}}{1[V_{Peak}]})$
dBm	Power in relative to 1[mW]. Please notice, that every dBm result refers to the actual input impedance, as e.g. 600Ω.	$dBm = 20 * \log_{10}(\frac{U_{RMS}}{\sqrt{1[mW] * R_{In}[\Omega]}}) = 10 * \log_{10}(\frac{P}{P_0})$
dBm0	dBm referred to or measured at a point of zero transmission level.	
dBrn	dB above reference noise. Weighted circuit noise power in dB referred to 1pW @ 600[Ω]which is defined as 0dBrn (-90dBm). Type of weighting is indicated by next letter (see dBrnc).	$dBrn = 20 * \log_{10}(\frac{U_{RMS}}{\sqrt{1[pW] * R_{In}[\Omega]}})$
dBrnc	Weighted circuit noise power in dBrn, acquired on a line by measuring set with 'C' message weighting.	
dBrnc0	Noise power measured in dBrnc referred to zero transmission level point (0TLP).	$dBrnc0 = dBrnc - 10 * \log_{10}(\frac{R_{Load}}{600[\Omega]})$

6 SPECIFICATIONS

Generator

Number of channels	2
Generator type	multitone arbitrary
Resolution	16bit
Sampling rate	48kHz
Frequency resolution	5.86Hz @ blocklength 8192
Number of signal memories	4 (stereo)
Number of test signal frequencies	1 to 31
Signal Frequencies	20Hz to 20kHz
Multitone burst duration	260ms to 960ms depending on frequency resolution max. up to 30sec or continuous (programmable)
Residual distortion	< -86dB or 10µV
Output Level Symmetric	-60 to +20 dBVp in 0.1dB steps (for each channel individually)
Level accuracy	< 0.2dB (@ 1kHz)
Flatness	< 0.2dB (20Hz to 20kHz)

Analyzer

Measurement functions	Level, Total Distortion, Noise, Interchannel Phase, Crosstalk (measured simultaneously)
Number of channels	2
Resolution	18bit
Sampling rate	48kHz
Residual distortion	< -86dB (input signal > -15dBVp)
Frequency resolution	2.95Hz minimum
Input Range (bal.)	-60 to +20 dBVp
Level accuracy	< 0.2dB (@ 1kHz)
Flatness	< 0.2dB (20Hz to 20kHz)
Synchronization	Internal or External
Measurement turn around time	800ms @ blocklength 512 and 3 signal bins

General

Dimensions	483 x 318 x 44 mm (19" x 12.5" x 1.75" - 1 rack unit high)
Weight	7kg
Remote control	IEEE-488
Power requirements	100/120/230V, 50/60Hz, 60VA
Calibration	1 year recommend calibration interval
Operating temperature	5°C to 45°C (40 to 110F) with R.H. < 90% non condensing

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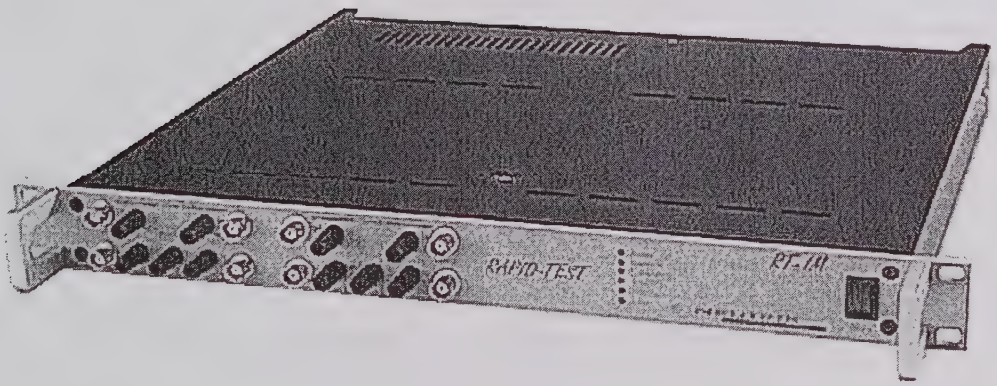
Application Hints

Introduction to

RAPID-TEST



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V 2.0 / Apr. 98 / MBe, PhS
\\NEUTRIK-NT\PHS1\RT-1M\APP_NOTE\Introduc\Intro_20.doc

ABSTRACT

With the RAPID-TEST instruments, NEUTRIK offers a series of powerful multitone analyzers for an extremely fast, yet precise audio performance analysis. Each type of the series allows the 2-channel analysis of frequency response, distortion, noise, phase and crosstalk within a minimum of time.

GENERAL INFORMATION

Multitone Signal Analysis

Conventional audio test sets normally transmit single sine waves for signal analysis. On the other hand, RAPID-TEST generates and analyses multitone signals, i.e. a mixture of several sine waves with different frequencies. Displayed on an oscilloscope, a multitone signal almost resembles noise, while on a spectrum analyzer the single frequencies become visible.

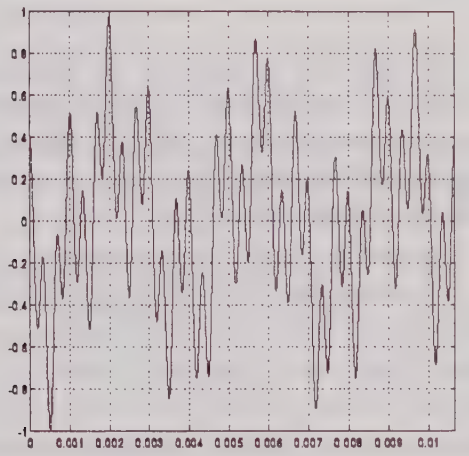


Fig 1 Time Plot of 3-Freq. Multitone Signal

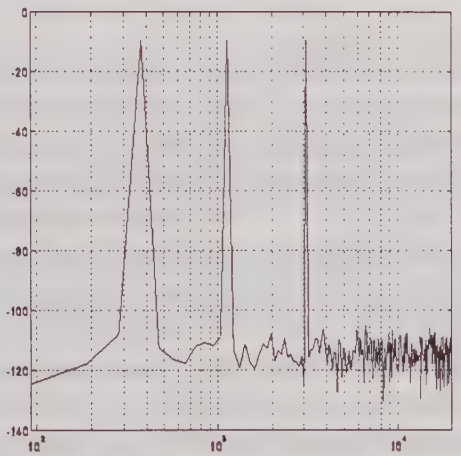


Fig 2 Spectrum of 3-Freq. Multitone Signal

One major advantage of multitone signals is that they correspond much closer with real world signals like human speech or music than any single sinusoidal wave (especially when testing data reducing devices).

Furthermore, since several audio parameters may be measured in one step lasting only fractions of a second, all applications where time is a bottleneck profit from the enormous analysis speed with multitone signals.
In practice, multitone signal analysis ideally fits for virtually any application where audio transmission characteristics of a component, line or system shall be evaluated.

Please notice, that RAPID-TEST is available either with analog-only or analog & digital (ISDN) in-/outputs.

3 Evaluation of Loudspeakers / Microphones

Goal Measurement of the electroacoustic parameters (frequency response, distortions, noise, phase shift, crosstalk) of a microphone or speaker.

Set-Up

- Install an (active) loudspeaker and a precision microphone with known characteristics at defined positions in an anechoic chamber.
- Connect the output of RAPID-TEST to the loudspeaker and the input to the microphone

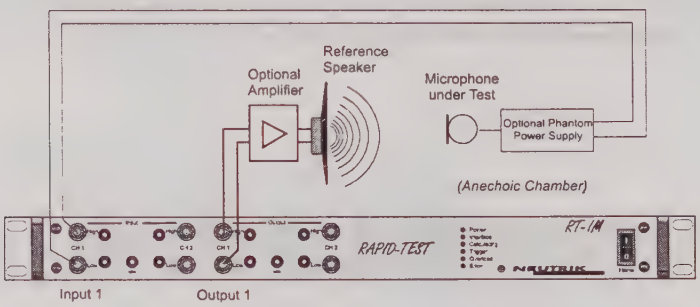


Fig 6 Microphone Test

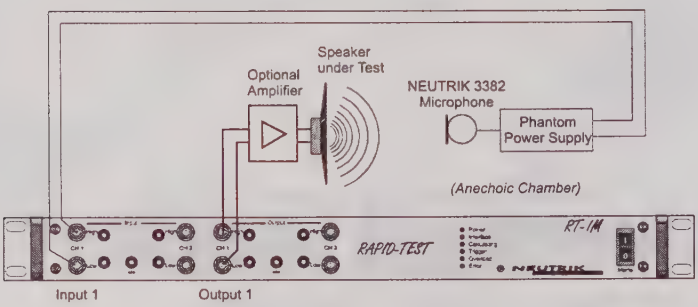


Fig 7 Loudspeaker Test

Procedure

- Define a multitone signal in the frequency range of interest.
- Measure all audio parameters of interest and store the results as reference.
- Install the transducer to be measured instead of the reference (position must be identical!) and repeat the measurement.
- Calculate the difference between the result of the second test to your reference data in order to establish the characteristics of your DUT.

4 Arbitrary Signal Generator

Goal Definition and generation of arbitrary signals, which may either be transmitted for a certain number of times or endlessly.

In this mode, the generator module of RAPID-TEST is used only.

Set-Up

- Connect output channel(s) of RAPID-TEST to the device under test (DUT).

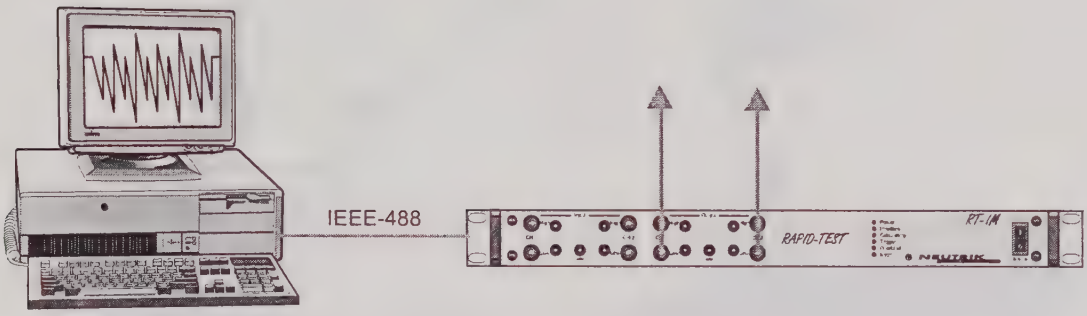


Fig 8 RAPID-TEST as Arbitrary Signal Generator

Procedure

- Define a (multitone) signal on the RAPID-TEST generator.
- Send the signal each desired time or repetitively.

5 Transmission Line Testing

Goal To measure long distance transmission lines, the output of the sending RAPID-TEST must be connected to the base station of the transmission line. The receiving RAPID-TEST (also several analyzers are allowed) and their host PCs may be located anywhere you like.

Set-Up
- Define a multitone signal and feed it through the transmission line.
- Arm the listening RAPID-TEST units and gather the measured data from their host PCs (e.g. through a Modem link).

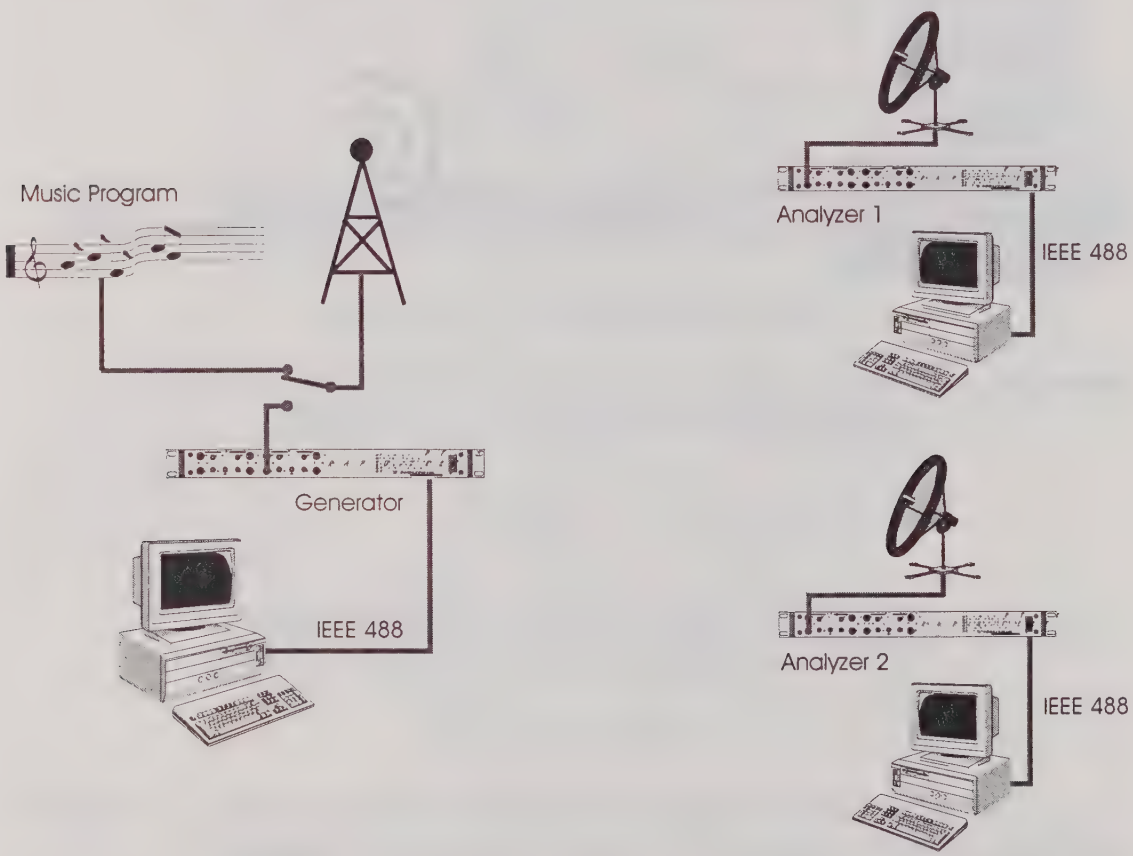
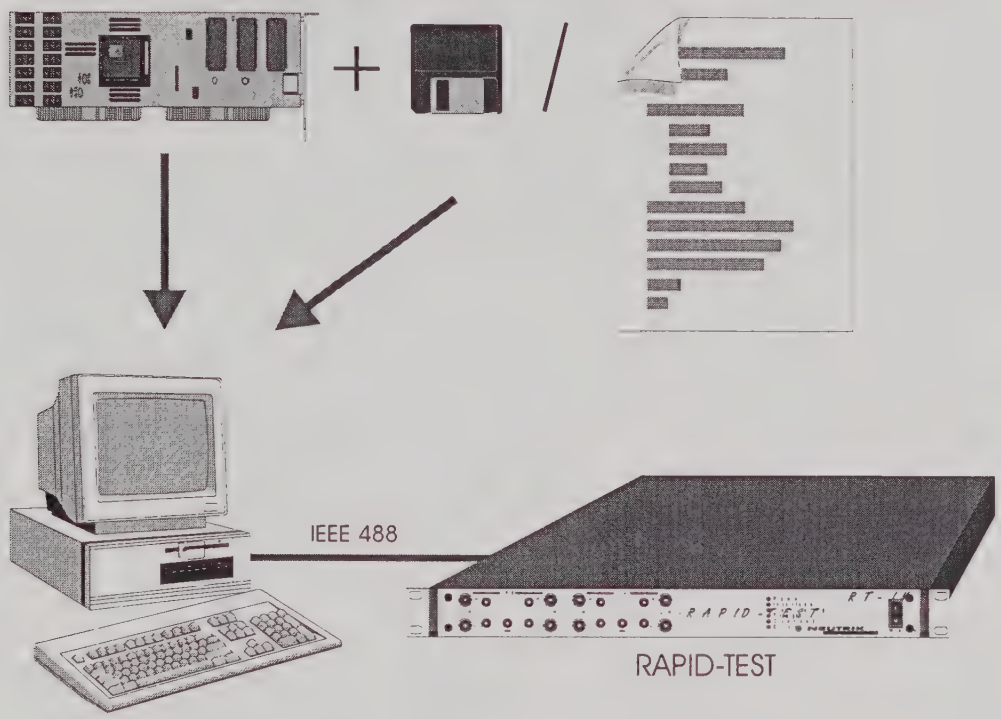


Fig 9 Transmission Line Test

Please notice that for radio transmission tests, the broadcast program must be interrupted shortly to introduce the multitone burst.

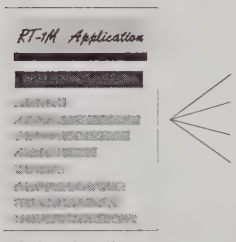
RAPID-TEST PRODUCT OVERVIEW

GPIB Board from National Instruments™ + RT-EVAL or LabWindows CVI or LabView driver library or application-specific Program (C, BASIC etc.)

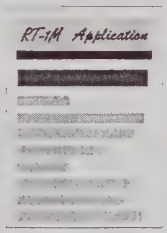


Application Notes

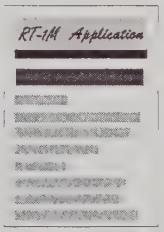
(ask your local NEUTRIK representative for a copy)



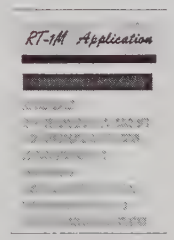
Introduction



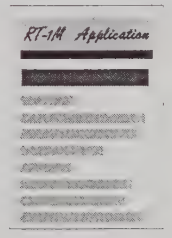
Get Familiar with Writing Code



Cellular Phone Testing



Comparing Conventional vs. Multitone Testing

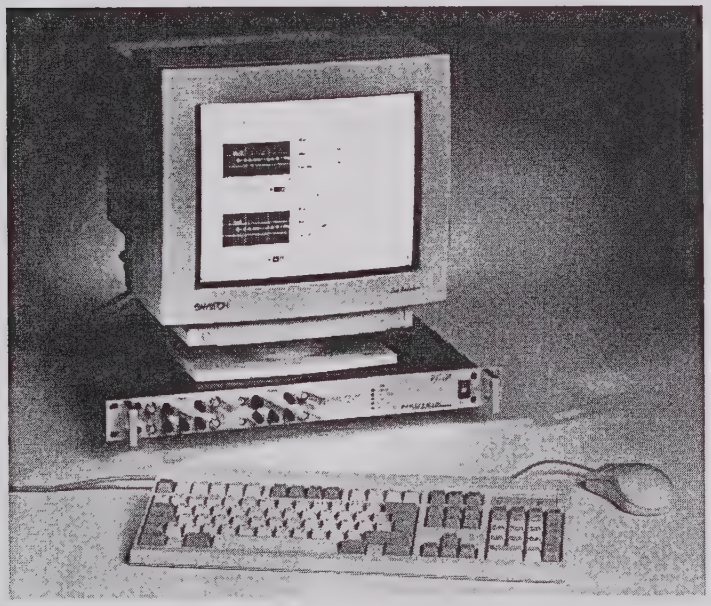


Speakers & Microphones*

*: to be released

Application Note

RAPID-TEST



Get Familiar with Writing Code for RAPID-TEST

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ABSTRACT

RAPID-TEST is a sophisticated measurement system for the fast and accurate analysis of the five standard audio parameters Level, Distortion, Noise, Xtalk and Phase. It takes advantage of the advanced multitone technique and was designed especially for industrial applications, where speed and automated remote control are of prime interest.

This application note describes how to get familiar with the programming demands of RAPID-TEST. It assists the user step-by-step to set up the system, perform first measurements and to interpret the results properly. Several program examples and hints are included in order to provide a useful base for individual solutions.

Assumptions

This document was written for the application engineer who wants to integrate RAPID-TEST into an automated environment, e.g. a test stand in a production line. Therefore, it is supposed that the reader provides a basic understanding of the subsequent topics.

- Knowledge of the standard audio measurement functions such as frequency response, distortion (or SINAD), noise etc. and conventional measurement methods.
- Characteristics and typical applications of multitone signals.
- Writing software in a language like BASIC, LabView®, C, PASCAL etc. in order to remote control a peripheral instrument through an IEEE parallel interface.

All listed programs are written with TransEra™ HT-BASIC. However, any other programming language providing the required I/O commands etc. may be used as well.

Please notice that NEUTRIK also offers the Windows®-based evaluation software RT-EVAL, comprising a code-generator feature, as well as a LabView® and LabWindows® driver library free of charge.
However, this paper will not refer to these packages, but instead provide an overview on the programming of RAPID-TEST without these tools.

Required Equipment

On the hardware side, it is assumed that RAPID-TEST is connected to the controlling PC through a GPIB IEEE-488.2 parallel interface. NEUTRIK recommends to use one of following interfaces from NATIONAL INSTRUMENTS™

- GPIB-PCMCIA
- GPIB-PCII/IIA (production year 1992 or later)
- GPIB/TNT

NOTES **The examples in this document refer to the IEEE address set to #3, but keep in mind that RAPID-TEST can be set to any other IEEE address as well.**

All subsequently listed commands are supported by RT-1M as well as RT-2X. However, they do not cover the complete range of available features of these two instrument types.

QUICK GUIDE

Set-up and Function Check

First of all, it is essential to establish proper communication from the controlling PC to RAPID-TEST through the IEEE interface. To check this, enter the subsequent command while watching the LED labeled 'Interface' at the front panel of the unit.

```
OUTPUT 703;"SYSTEM:ERROR?"
```

`OUTPUT 703;"..."` states that the string enclosed in brackets is sent via the IEEE interface to address No. 3, while the core of the command, `SYSTEM:ERROR?`, is the RAPID-TEST instruction that queries for the last errors which occurred in the unit.
Every time, that this string is transmitted to RAPID-TEST, the Interface LED has to light up. Furthermore, since this query forces the unit to delete its error stack, the LED 'Error' must go off afterwards.

Do not continue unless you have ensured proper communication. If the Interface LED should not light up, check whether the IEEE address, encoded in the command, and the IEEE address of RAPID-TEST correspond with each other. Alternatively, try command

```
OUTPUT 703;"SYSTEM:RESET"
```

that generates a hardware reset in the unit. You will hear some relays clicking and all LEDs will light up for a second. The system will be immediately ready to accept new commands afterwards.

NOTE	**Depending on your PC programming language & environment, you may have to add an END command to tell the interpreter to send off the string.**

Basic Signal Definition

Every RAPID-TEST has default signals stored in each of its four memory locations when delivered.

- Memory #1 stores a typical 3-tone signal (281Hz, 1031Hz, 3000Hz) for telecom applications
- Memory #2 stores a pure 1kHz sine signal
- Memory #3 stores a similar 3-tone signal (305Hz, 1008Hz, 3000Hz) as in memory #1
- Memory #4 stores a 29-tone signal with a bandwidth of 23Hz to 19049Hz

These signals are all defined identically on both channels and may of course be used if they fit into an application (see *Appendix*). However, since most RAPID-TEST applications requires specific multitone signals, it is vital to know how to define a new signal.

Please notice that this chapter provides a rough overview on signal programming only. A more detailed description of this topic, comprising a list of all available parameter and their explanation is filed in chapter *Detailed Approach*.

NOTE	**In this document, the frequencies that actually build a multitone signal are called *signal bins*.**

Multitone Burst Components

For proper understanding of the subsequent chapters, it is vital to know the differences between the terms "multitone signal" and "multitone burst".

A *multitone burst* comprises several components starting with a trigger, followed by a synchronization block and ending with the multitone signal.

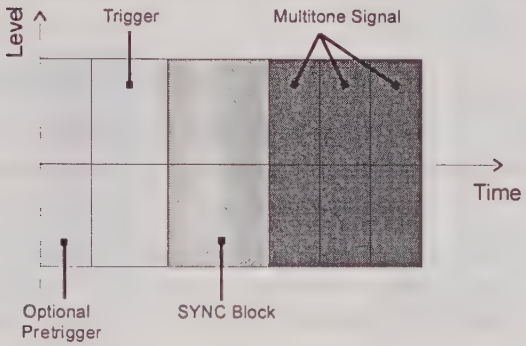

Fig 1 Multitone Burst Components

- Optionally, a *pretrigger* may be introduced in order to compensate the transient behavior as of automatic gain controls (AGC) or noise gates, that are part of the test circuit (see p. *20*).
- The *trigger* is a predefined signal that 'identifies' the burst as coming from a RAPID-TEST generator. This allows any listening analyzer to recognize the origin of an incoming burst.
- The *SYNC block* is a 3kHz signal of fixed length, that enables the analyzer to synchronize itself onto the generator sample rate, if necessary (see p. *19*).
- The *multitone signal* contains the user-defined signal bins and is used for analysis of the audio parameter. It may be repeated several times if required to let the DUT stabilize.

Further details about multitone burst components are filed in the ***User Manual***.

Multitone Signal Definition

Basically, there exists one command for the definition and storage of a new multitone signal.

```
OUTPUT 703; "OUTPUT:MTONE:PARAMETER ..."
```

It is followed by a certain number of values, setting the compulsory parameters of every multitone signal. This list may range from 9 parameters (multitone burst with 1 signal bin per channel) to 129 parameters (multitone burst with 31 signal bins per channel).

NOTE	**The signal definition procedure has to be performed only, if a new multitone signal has to be introduced. Defined signals are kept in the non-volatile memory of RAPID-TEST even during power off.**

Parameter	*Type*	*Range*	*Explanation*

SignalNumber	integer	1-4	Target memory of RAPID-TEST
SignalName	char	≤ 8 ASCII characters	User-defined name, enclosed in apostrophes (')
NumberOfSamples	integer	512, 1024, 2048, 4096, 8192	Blocklength (see p. *11*)
NumberOfBinsChn1	integer	1-31	Number of signal bins to be transmitted in channel 1
NumberOfBinsChn2	integer	1-31	Number of signal bins to be transmitted in channel 2
BinNumbersChn1	integer	1-3413 (depending on blocklength)	Bin-number (i.e. frequency) for each signal bin of channel 1 (see p. *13*)
BinNumbersChn2	integer	1-3413 (depending on blocklength)	Bin-number (i.e. frequency) for each signal bin of channel 2 (see p. *13*)
PhasesOfBinsChn1	float	0 to ±π (±3.14159)	Phase of each signal bin of channel 1 (see p. *13*)
PhasesOfBinsChn2	float	0 to ±π (±3.14159)	Phase of each signal bin of channel 2 (see p. *13*)

Table 1 Multitone Signal Parameter

When defining a multitone signal, following rules have to be obeyed.

- The parameters have to be listed in the indicated order and must be separated by commas (,)
- It is compulsory to assign a value to each parameter, even if it is 0; however, it is allowed to assign an empty string ('') to the parameter *SignalName*.
- The blocklength must equal one of the available values.
- The number of signal bins for channel 1 / 2 may differ from each other.
- The values of parameter *BinNumbersChnX* correspond to the signal bins of the multitone signal. Each value may be calculated according to

$$BinNumber = \frac{NumberOfSamples}{48000} * f_{bin}$$

Equation 1 Signal Bin Number Calculation

wherein f_{bin} indicates the frequency of the respective signal bin (the bin number needs to be rounded to the next integer value). There must be defined as many signal bins as indicated by the value of the parameter *NumberOfBinsChnX*.

- The phases of the signal bins must be indicated in radian (±π corresponds to ±180°).

Example

Following example defines a multitone signal with different signal bins in channel 1 and 2.

```
OUTPUT 703; "OUTPUT:MTONE:PARAMETER 2,'example',512,2,3,1,12,11,100,213,
  0,0,0,-3.14159,0.12345,1.00000"
```

⇒ The signal will be stored in memory #2

⇒ The name of the signal will be "example"

⇒ The number of samples (i.e. blocklength) is 512

⇒ Channel 1 comprises two signal bins. The number of the first signal bin is 1 (94Hz[1]), while the number of the second is 12 (1125Hz)

⇒ Chn. 2 comprises three signal bins, number 11 (1031Hz), 107 (10031Hz) and 213 (19969Hz)

⇒ The phases for both tones of channel 1, expressed in radian (degrees) are 0 (0°)

⇒ The phases for the three tones of channel 2 are -π (-180°), 0.12345 (7.1°) and 1.0 (57.3°)

How to get Measurement Results

Basically, there is one important thing to know about the way RAPID-TEST calculates any audio parameter.

NOTE	**RAPID-TEST first stores a received a multitone burst in its internal memory, and afterwards calculates those measurement result(s) that are queried by the user.**

Consequently, it is sufficient to transmit a multitone burst once only, while evaluation of the required audio parameter values happens any time afterwards, and may even repeated as many times as necessary.

In practice, it is possible to calculate up to five different audio parameter out of the stored raw data, that were extracted from a received multitone burst. The corresponding commands are

```
OUTPUT 703; "MEASUREMENT:LEVEL?"
OUTPUT 703; "MEASUREMENT:DISTORTION?"
OUTPUT 703; "MEASUREMENT:NOISE?"
OUTPUT 703; "MEASUREMENT:PHASE?"
OUTPUT 703; "MEASUREMENT:CROSSTALK?"
```

The syntax of the returned values is almost identical for each of these audio parameter.

```
Bin1/Value1,Bin2/Value2,...,BinN/ValueN
```

wherein `BinX` indicates the number of the set signal bins in rising order, while `ValueX` is the calculated measurement result. For further details, refer to the ***User Manual***.

[1] $\frac{48000}{NumberOfSamples} * BinNumber = \frac{48000}{512} * 1 = 94Hz$

DETAILED APPROACH

Complete Signal Definition

The most important step when designing a multitone signal is to be aware of the true requirements of the application. In other terms, it is vital to adapt every new multitone signal together with all its parameters exactly to the requirements of the complete set-up.

For instance, it might be necessary to measure the frequency response of a radio set with a bandwidth of 300Hz to 3kHz by using some test equipment featuring a response time of 500ms. Obviously, in this case it would be useless to define a multitone burst of 300ms length, comprising frequencies over the complete audio range (20Hz-20kHz).

Therefore, it is necessary to consider all setable parameters of the multitone burst

- Memory location and signal identification — ***compulsory***
- Signal bins / bandwidth — ***compulsory***
- Number of samples / blocklength — ***compulsory***
- Phases / Crest factor — ***compulsory***
- Output level — *optional*
- Input range — *optional*
- Pretrigger length — *optional*
- Number of cycles, i.e. multitone burst length — *optional*
- Connections to front or rear — *optional*
- Float / ground mode — *optional*
- Synchronization mode — *optional*

Obviously, there are two classes, the compulsory parameters that must be defined, and optional parameters, for which default values exist. However, it is strongly recommended at least to check whether these default values of the optional parameter fit to the actual demands.

Compulsory Parameters

All compulsory parameters must be defined in the parameter list of `OUTPUT:MTONE:PARAMETER`, which is the core command for any multitone signal definition.

Signal Identification

The first two parameter in the list are for signal identification. The *SignalNumber* indicates the target memory of RAPID-TEST while the *SignalName* enables the user to 'label' each signal with an individual name. Both parameter are freely selectable by the user within the defined range.

Parameter	Type	Range	Example
SignalNumber	integer	1, 2, 3, 4	3
SignalName	char	≤ 8 ASCII characters, enclosed in apostrophes	`'sine1khz'`

Table 2 Signal Identification Parameter

Number of Samples / Blocklength

The third parameter to be defined within command `OUTPUT:MTONE:PARAMETER` is the *NoOfSamples*, also called 'blocklength' of the multitone signal. This term indicates the number of sample points that are used to represent the complete multitone signal. For better understanding, please refer to *Fig 2*.

The picture shows a multitone signal in the time domain, wherein the curve represents the signal level vs. time (Y-axis = level, X-axis = time).
At this point you must be aware that the generator of RAPID-TEST sends out a certain number of level values only, which all together represent the multitone signal. These level values (indicated by dots) are generated at fixed time intervals. In RAPID-TEST, this time interval equals 21µs, resulting from the internal sampling rate of 48kHz.

$$\frac{1}{48000\,Hz} = 21\,\mu s$$

Equation 2 Sampling Interval of RAPID-TEST

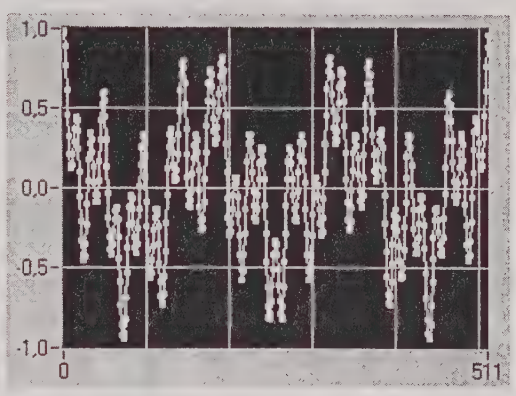

Fig 2 Signal Sampled with Blocklength 512

Remains the question, how many of these level values are necessary to represent a multitone signal good enough? The answer can be given by looking on its two most important consequences.

Signal Duration

First, it is obvious that the more samples are used for representation of a signal (i.e. the longer the blocklength), the longer becomes its duration. In practice, each of the available blocklengths corresponds to a typical signal duration.

Blocklength	512	1024	2048	4096	8192
Min. burst duration (w/o header)	154ms	284ms	344ms	684ms	854ms
Typ. burst duration (w/ header)	260ms	390ms	450ms	790ms	960ms

Table 3 Signal Duration vs. Blocklength

Keep in mind that the typical burst duration refers to a multitone burst comprising trigger, SYNC block and the multitone signals, but without an additional pretrigger or special multitone lengths (see p. 20). Consequently, the signal duration can either be increased by introducing at least one of the latter signal components or cut down by sending out the multitone signal without its header (see p. 19).

Frequency Resolution

Second, it is vital to know that only signal bins may be generated, of which the time period fits exactly for an integral number of times into the multitone signal duration. In other terms, it is not possible to set a signal bin with a period length equaling a fraction of the multitone signal length. For instance, it is obvious that a signal (bin) with a period length of 50ms cannot be represented by a multitone signal lasting for 11ms only.
Alternatively, one may also watch the consequences of this restriction in the frequency domain. Therein, the signal duration corresponds to the lowest possible frequency that may be generated. This minimum frequency, also called *frequency resolution*, may be calculated by

$$FrequencyResolution[Hz] = \frac{1}{Blocklength * 21\mu s}$$

Equation 3 Frequency Resolution

This means that signal bins with are an integral multiple of the frequency resolution may be generated within a multitone signal only.

Overview

These two relations may be visualized in one graph, thus enabling the operator to select the optimum blocklength for the application.

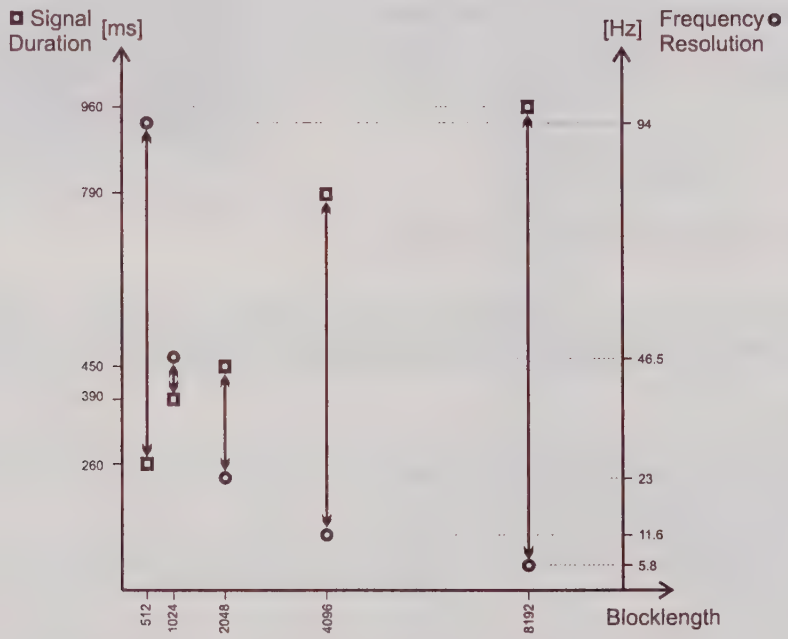

Fig 3 Blocklength, Signal Duration & Frequency Resolution

Keep in mind that in RAPID-TEST there are 5 different blocklengths available.

Parameter	Type	Range	Example
NoOfSamples	integer	512, 1024, 2048, 4096, 8192	512

Table 4 Available Blocklengths

As a rule of thumb it may be advisable to start with the shortest blocklength (512) in order to obtain maximum test speed. If the results are reproducible and correspond to conventionally measured values, this blocklength doesn't need to be changed anymore.

However, there might arise problems with unstable test results because of too short sampling intervals. In this case, the blocklength must be raised stepwise until sufficiently reproducible results are acquired.

Another argument for longer blocklengths is the need for signal bins in the lower audio frequency range. If, for instance, a signal bin close to 20Hz shall be set, a blocklength of at least 2048 is necessary.

Signal Bins

The next step of every multitone signal definition concerns the signal bins, i.e. the transmitted frequencies. In practice, there are two questions to be answered.

1. How many signal bins shall be transmitted?
2. At which frequencies shall these signal bins be set?

Number of Signal Bins

To answer the first question, one has to consider the specific test requirements of the audio parameter to be measured.

- To get a *level* plot, i.e. frequency response, it may be advisable to set a large number of signal bins, since this increases the resolution of the resulting graph.
- For *distortion* measurements, the situation is contrary. The larger the number of transmitted frequencies, the more intermodulation products are generated, resulting in a worsened comparability between the TD+N result of RAPID-TEST and a conventionally measured THD+N value. Therefore, it is recommended to minimize the number of signal bins for distortion tests.
- Concerning *noise* measurements it is a good approach to set few signal bins only in order to avoid intermodulation products, that could not be differed from noise.
- If the *phase* response of a DUT shall be evaluated, a larger number signal bins should be set in order not to omit dramatic changes of the phase shift.
- For *crosstalk* tests, it is sufficient to set few signal bins only.

Signal Bin Numbers

As soon as the number of signal bins has been set, each of them has to be assigned to a certain value, i.e. frequency. Although this step is almost obvious, three things have to be considered.

First, one has to define the frequencies of the lowest and the highest signal bin, thus determining the *bandwidth* of the multitone signal. A proper selection is of special importance, since it must consider the transmission characteristics not only of the test circuit, but also of the DUT.

Second, the frequency must be converted to the respective *BinNumber*, that may be evaluated by using following formula, wherein f_{nom} is the nominal (i.e. intended) frequency of the respective signal bin.

$$BinNumber = f_{nom} * Blocklength * 21\mu s$$

Equation 4 BinNumber Calculation

This conversion is necessary due to the processor of RAPID-TEST, that cannot deal with absolute frequency values, but must be fed with the converted signal bin numbers.

NOTE	**The calculated *BinNumber* must be rounded to the next integer value.**

Following hints may be helpful to set the signal bins to optimal frequencies.

- Do not set any two signal bins directly besides each other (e.g. at bin number 11 and 12). Instead, distribute them in a way that some unused bin numbers are between two set signal bins (e.g. at bin number 11 and 16). If two signal bins are set oo close, the returned measurement values of one of them may be "NaN" (not a number) instead of a number.
- A *level* plot, i.e. frequency response, provides the best result if the signal bins are distributed regularly over the logarithmic frequency axis.
- If a *distortion* measurement shall be made, it is best to set the signal bins between frequency bands of interest.
- *Noise* measurements should be calculated out of multitone signals with the signal bins being set at frequencies marking the borders of one or more range(s) of interest.
- For *phase* response evaluation, the signal bins should be distributed regularly over the frequency range of interest.
- *Crosstalk* tests require definition of different signal bins in channel 1 and 2. Furthermore, these bins should preferably be set at higher frequencies.

Phases & Crest Factor

The last parameter block of command `OUTPUT:MTONE:PARAMETER` comprises the *phases* of all signal bins. Definition of these values is necessary because of their impact on the *Crest factor*, that directly influences the dynamic range of the multitone signal.

The two following pictures provide a good impression about the meaning of the Crest factor.

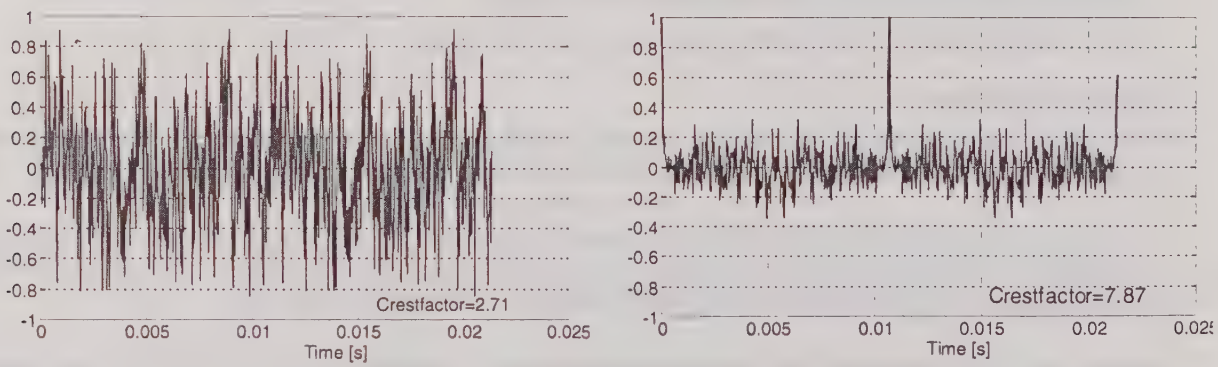

Fig 4 Signals with Low and High Crest Factor

In principle, the shown multitone signals comprise identical signal bins. However, they differ in the phases of these signal bins. Obviously, the phases of the left hand signal have been chosen in a good way, so that the amplitude of the signal is rather constant. On the other side, the phases of the right hand signal represent a rather frightful choice, resulting in periodical 'spikes' with a much bigger amplitude than the rest of the signal.

The consequences of a good or bad phase definition, i.e. of a low or high Crest factor are quite clear.

- In order to avoid clipping, the peak level of the multitone must not exceed the allowable peak level of the DUT. However, this requirement results in a low RMS level of a signal with high Crest factor, thereby reducing accuracy of distortion measurements and worsening the S/N ratio.

- The accuracy of every A/D converter becomes better the higher the RMS level of the incoming signal is. Therefore, analysis of signals with a low Crest factor show better results than of signals with high a Crest factor.

But how shall the programmer of a multitone signal define the phases in order to obtain a low Crest factor? The answer is rather simple - just define random phases for the signal bins. Even if this approach cannot assure the minimum Crest factor, it will result in a satisfyingly low value.

NOTE	**Never define identical phase values for all signal bins in your multitone signal. Instead, assign random phase values - especially to signal bins with low frequencies.**

Finally, one may wonder about the actual Crest factor of a stored signal. Fortunately, RAPID-TEST automatically carries out this calculation, of which the result may be queried by a simple command.

```
OUTPUTx:MTONE:CREST?
```

When sent to the unit, this instruction forces RAPID-TEST to send back a single value, equaling the Crest factor of channel *x* (parameter *x* must be set to either 1 or 2).

Remains the question whether the obtained value is good or not. To answer this, one must know that with increasing number of signal bins, the Crest factor always raises too. For instance, a value of 2.5 for a multitone signal with up to five signal bins is rather good, while optimized signals with 25 or more signal bins normally show Crest factors of up to 3.5.

Program Example

After having acquired all this knowledge on multitone signal definition, it is time to have a look on a typical program. Following example, written in BASIC, defines a multitone signal comprising 2 signal bins. It may be used as a base for your own programs.

```
10  REM --- Definition of a multitone signal ---
20  REM FS = Sampling frequency
30  REM BL = Block Length
40  REM NF = Number of frequencies (used as pointer for F[] and P[])
50  REM SN = Signal number (location 1..4)
60  REM ID$ = Name of multitone signal
70  REM F[NF] = Vector  with frequencies (to be defined by the operator)
80  REM P[NF] =  Vector with phases  (to be defined by the operator)
90  REM These variable have to be defined upon entry into the routine.
110 REM ------------------------------------------------
120 REM Variables Definition
140 DIM Out$[200]
150 DIM F(31)
160 DIM P(31)
170 REM ------------------------------------------------
180 REM Frequencies and phases definition
190 Sn=1
200 Nf=2            ! How many frequencies is the signal going to have?
210 F(1)=1000       ! 1000Hz
```

```
220 P(1)=0          ! Phase = 0
230 F(2)=1800       ! 2nd frequency is 1800Hz
240 P(2)=PI/3       ! 2nd phase is Pi/3
250 Fs=48000        ! Sampling frequency is 48kHz
260 Bl=2048         ! Block length is 2048
270 Id$="name"
280 Q$=CHR$(34)     ! Quote "
290 Df=Fs/Bl
300 REM Empty OUT$
310 Out$=""
320 REM ------------------------------------------------
330 REM Start definition of multitone signal
340 Out$="OUTPUT:MTONE:PAR "&VAL$(Sn)&","
350 Out$=Out$&Q$&Id$&Q$&","&VAL$(Bl)&","&VAL$(Nf)&","&VAL$(Nf)
360 REM ------------------------------------------------
370 REM --- Add frequencies channel 1
380 FOR I=1 TO Nf STEP 1
390    Out$=Out$&","&VAL$(INT(F(I)/Df+.5))
400 NEXT I
410 REM --- Add frequencies channel 2 (identical)
420 FOR I=1 TO Nf STEP 1
430    Out$=Out$&","&VAL$(INT(F(I)/Df+.5))
440 NEXT I
450 REM --- Add phases channel 1
460 FOR I=1 TO Nf STEP 1
470    Out$=Out$&","&VAL$(P(I))
480 NEXT I
490 REM --- Add phases channel 2 (identical)
500 FOR I=1 TO Nf STEP 1
510    Out$=Out$&","&VAL$(P(I))
520 NEXT I
530 REM --- Output the complete string
540 OUTPUT 703;Out$ END
550 PRINT Out$;"  ";Err
560 IF Err=0 THEN PRINT "Signal definition O.K."
570 GOSUB Error_check
590 REM ------------------------------------------------
600 REM Read back stored signal
610 Out$="OUTPUT:MTONE:ACTIVE "&VAL$(Sn)
620 OUTPUT 703;Out$ END
630 Out$="OUTPUT:MTONE:PARAMETER?"
640 OUTPUT 703;Out$ END
650 ENTER 703;Rcv$
660 PRINT "Stored signal is: ";Rcv$;
670 GOSUB Error_check
680 Out$="OUTPUT1:MTONE:CREST?"
690 OUTPUT 703;Out$ END
700 ENTER 703;Rcv$
701 !PRINT "Crest$ = ";Rcv$
710 Crest1=VAL(Rcv$)
720 PRINT "  cf= ";Crest1
730 GOSUB Error_check
```

```
740 STOP
760 Error_check:
770 REM --- Check for errors
780 OUTPUT 703;"SYSTEM:ERRORS?" END
790 ENTER 703;Rcv$
800 Err=VAL(Rcv$)
810 SELECT Err
820    CASE 151
830    PRINT "You must define phases as float numbers"
840    CASE 152
850    PRINT "The phase value(s) are out of range"
860    CASE 153
870    PRINT "SignalNumber, Blocklength or NoOfBins was not an integer"
880    CASE 154
890    PRINT "Integer parameter are out of allowed range"
900    CASE 155
910    PRINT "String parameter expected"
920    CASE 160
930    PRINT "Signal name must not have more than eight characters"
940    CASE 161
950    PRINT "Blocklength must be 512,1024,2048,4096 or 8192"
960    CASE 162
970    PRINT "Frequencies defined out of range"
980    CASE 0
990    !PRINT "No error occurred"
1000 END SELECT
1010 RETURN
1020 END
```

Listing 1 Definition of Multitone Signal

⇒ The variables are initialized in lines 180 to 280. However, the program could also be re-written in a way that the values are handed over to the program as parameter.

⇒ The two frequencies and phases are defined in the vectors f() and p(). In the lines 330 to 250 the string for the multitone definition command is built. Values of the frequencies and phases for both channels are added to the string in the four `FOR..NEXT` loops in the lines 380 to 520. The string is sent to RAPID-TEST in line 540 and the error check subroutine is called (see below).

⇒ The next sequence in the lines 600 to 720 is for querying the system for the actually stored multitone signal including the resulting Crest factors for confirmation.

⇒ The error check subroutine sends out the query string for errors. The result is an error number. Depending on the error number either an error string is created or the number is printed out.

This simple program is of course just a sequence that shows one of several possible approaches to define a new multitone signal. A more straightforward solution would be to enter the parameter directly into the output commands or to read the frequencies and phases from an external file.

NOTE **The signal definition procedure has to be performed only if a new multitone signal has to be introduced. Defined signals are kept in the memory of RAPID-TEST even during power off.**

Optional Parameters

Before the first measurement can be carried out, some further settings have to be done in order to ensure that RAPID-TEST is properly configured. These settings are

- Input connection to front or rear panel
- Float / ground mode
- Synchronization mode
- Pretrigger length and multitone length
- Output level
- Input range

Input Connection

The signal I/O cables to/from RAPID-TEST can be connected either to the front or to the rear panel of the instrument. In any case, this selection must not only be done physically by plugging in the connectors at the respective panel, but also has to be loaded into the internal memory of RAPID-TEST. The command for this procedure is

```
INPUT:FRONT xx
```

wherein *xx* must be set to either `ON` (front panel active) or `OFF` (rear panel active). The default setting of RAPID-TEST is `ON`, i.e. activation of the front panel.
Anyway, one has to ensure during set-up that the chosen setting corresponds to the physical wiring. Make sure that the not used in- & outputs are not connected, since an unexpected low impedance wiring on the input side can falsify your measurements and cause troubles in error localization.

Keep in mind that the mentioned command selects the inputs only. The outputs of RAPID-TEST are wired up in parallel, i.e. the sent-out signal is always present at the front as well as at the back connectors, regardless of the input selection.

Float / Ground Mode

The float / ground mode selection defines whether the generator ground is electrically isolated from the analyzer ground (chassis) or not. Each of these two grounds is available at the respective BNC and center banana connectors.

For normal balanced operation it is recommended to use the *float* mode. When using the RAPID-TEST in an unbalanced configuration, it is recommended to use the *ground* mode in order to ensure that a proper ground connection on the same level is made.

To select between the float and ground mode use command

```
OUTPUT:FLOAT xx
```

wherein *xx* must be set to either `ON` (activate float mode) or `OFF` (activate ground mode). RAPID-TEST default selection is the float mode.

Please notice that the first delivered units of RAPID-TEST did not feature the float option. The firmware of these instruments does not accept this command but returns an error 130 ("command is not available"). However, retrofit of the float option is possible at any time for these units. Please contact your nearest NEUTRIK representative if necessary.

SYNC Mode

This parameter defines the synchronization mode between generator and analyzer. In practice, there are two decisions to be made.

- Shall the multitone signal be preceded by a header or not?
- Shall the analyzer be connected to the same sample frequency clock as the generator or shall this frequency be calculated out of the incoming signal?

The optional header contains a trigger signal, followed by a 3kHz tone called SYNC block (see *Fig 1*). The trigger identifies the burst as coming from an RAPID-TEST, while the SYNC block allows the analyzer to synchronize its sampling frequency to the one of the received multitone burst.

Following command sets the SYNC mode of RAPID-TEST, wherein *xxx* must be set to one of three available selections (`INT`, `INTN` or `EXT`).

```
INPUT:SYNC:xxx
```

NOTE	**Regardless of the selected SYNC mode, the multitone burst is immediately sent off when the unit has received command `OUTPUT:MTONE:START` from the PC. Furthermore, the transmitted burst must arrive at the analyzer inputs within the time frames indicated below.**

INTernal

`INTernal` means that analyzer and generator are located in the same housing, both using the internal sampling clock. The multitone burst comprises header and multitone signal. Transmission time of the burst must not exceed 1s.
This mode shall be used as a standard , i.e. for all normal applications where the multitone burst is generated and analyzed in the same unit. However, test circuits generating a frequency shift, may require the `EXTernal` mode.

INTNoheader

`INTNoheader` is almost identical to the above mode, however, in this case the header is not transmitted. In other terms, the analyzer and generator are located in the same housing, both using the internal sampling clock, and the transmitted multitone burst does not comprise a header. Transmission time of the burst must not exceed 50ms.
Possible reasons to use this mode are

- Noisy environments
- Analysis of externally (i.e. not by a RAPID-TEST) generated signals as e.g. ringer or DTMF signals
- Problems with error 203 (no trigger detected)

EXTernal

`EXTernal` mode forces the analyzer to synchronize itself onto the SNC block of the incoming multitone burst. The sent off burst comprises header and multitone signal. Analysis of an externally generated signal (i.e. not coming from a RAPID-TEST) is not possible. Transmission time of the burst must not exceed 1s.
Typical applications for this mode are set-ups where frequency shifts occur in the test circuit or where the generator is localized remotely from the analyzer, i.e. if there are two RAPID-TEST units used, one for signal generation and one for its analysis.

Pretrigger & Multitone Length

These two parameter directly influence the signal duration of the complete multitone burst, however by two different means.

- A *pretrigger* is a predefined signal with selectable duration, that optionally may be added before the trigger signal. It is recommended to introduce a pretrigger for all test circuits with an instrument featuring automatic gain control (AGC) or similar, i.e. if the multitone burst has to be transmitted through an instrument with transients (slew rates) longer than 5 to 10ms.
- The parameter *multitone length* prolongs the multitone burst by repeating the multitone signal a certain number of times. This option is useful in test circuits comprising complex filters that cause group delays, where the frequency content of the multitone burst influences the gain of an AGC element or with noise gates etc.

The two commands for definition of these parameter both require definition of the intended duration *xx*, expressed in [ms].

`OUTPUT:MTONE:PRETRIGGERLENGTH` *xx* and
`OUTPUT:MTONE:MTONELENGTH` *xx*

Both parameter range from 0 to 30000ms (30 seconds) with a default value of 0. In practice, typical values for pretrigger lengths are 30ms to 500ms, while the multitone length usually needs not to exceed 1000ms.
Keep in mind that in the latter case, the multitone length always will be rounded to the next integral multiple of $Blocklength * 21E^{-6}$.

Output Level

With a standard audio generator, selection of the output level is as simple as determining the desired RMS level. With RAPID-TEST, selection of the output level of a multitone signal is equally simple, but requires a more detailed approach of how you want to define the desired levels.

When dealing with multitone signals we usually first have to consider the *total output level*, that can be quantified either as RMS level (energy) or peak level. The relation between these two levels is

$$\hat{U}_{mult} = U_{mult(RMS)} * c_f$$

Equation 5 RMS to Peak Level Conversion

wherein c_f is the well-known Crest factor. For instance, it may be desired to define the total output level expressed in Volts RMS of certain a multitone signal. In this case, we have to ensure that there is enough headroom provided by the DUT to accept the occurring signal peaks. Therefore, one may calculate allowed U_{mult} by using the peak level corresponding to the available headroom and the Crest factor of the signal.

Alternatively, one may also define the level of a multitone signal by setting the level of its signal bins. All signal bins have the identical level, called *bin level*, that may defined through a command (see below). This bin level is of course lower than the total output level of the multitone signal, and may either be expressed in peak Volts [Vp] or RMS Volts [V].
The relation between the RMS value U_{mult} of the total output level and the bin level U_{bin} is

$$U_{bin} = \frac{U_{mult}}{\sqrt{n}} \quad \text{or} \quad U_{mult} = U_{bin} * \sqrt{n} \quad \text{where } n \text{ is the number of signal bins}$$

Equation 6 Total RMS Output Level and RMS Bin Level

When dealing with the peak values $\hat{U}_{mult}$ of the total output signal and $\hat{U}_{bin}$ of the bin level, the equation can be expressed as

$$\hat{U}_{bin} = \frac{\hat{U}_{mult} * \sqrt{2}}{\sqrt{n} * c_f} \quad \text{or} \quad \hat{U}mult = \frac{\hat{U}bin * \sqrt{n} * c_f}{\sqrt{2}} \quad \text{where } n \text{ is the number of signal bins}$$

Equation 7 Total Peak Level and Peak Bin Level

Commands

According to the two mentioned approaches for signal level definition, there are two different commands available, one for the total output level and the other for the bin level.

```
OUTPUTx:LEVEL y z
OUTPUTx:BINLEVEL y z
```

wherein *x* indicates the channel, *y* the level value and *z* the unit of the chosen level value. For both commands, there are four units available, *V* (Volt RMS), *dBV* (decibel Volt RMS), *Vp* (Volt peak) and *dBVp* (decibel Volt peak). V and Vp represent linear scale, while dBV and dBVp are used for logarithmic scales. Both scales can be converted into each other by

$$U[dBV] = 20 * \log_{10}(U[V]) \quad \text{or} \quad U[V] = 10^{(\frac{U[dB]}{20})}$$

Equation 8 dBV to V Conversion

The subsequent example shall illustrate the level setting procedure

```
10 REM Define the total output level to be 0dBV
20 REM Print out the corresponding level expressed in V
30 REM ------------------------------------------------
40 Level = 0                                        ! dBV
50 OUTPUT 703;"OUTPUT1;LEVEL "&VAL$(Level)&" dBV"
60 PRINT "The set dBV level equals ";10^(Level/20) ;" V"
```

Listing 2 Setting of a Total Output Level

Alternatively, the total output level could be set in Volt, Vp or dBVp as well by simply replacing the "dBV" in line 50 by a "V", "Vp" or "dBVp". However, in any case it is vital to choose the level value according to the allowed range as listed in the ***User Manual***.
The bin level of an output signal may be defined simply by inserting the keyword "BINLEVEL" instead of "LEVEL" in line 50.

NOTE	**The levels have to be set for both channels individually, since there exists no command to set them simultaneously.**

Input Range

The last step to prepare RAPID-TEST for a measurement is to set the input range to a value as low as possible, but high enough to avoid any overload. The proper adjustment of this parameter is of special importance, since it is responsible whether an incoming multitone burst can be detected at all and whether the measurement results are correct. The command to set the input range of RAPID-TEST is

```
INPUT:RANGE x y
```

wherein *x* is the value of the input range and *y* the unit, that may be either *Vp* or *dBVp*. In practice, it is recommended to assume an input range and watch the LED "Overload" on the front panel of RAPID-TEST during transmission of a multitone burst.

- If the LED lights up, the input range has to be increased until the LED goes out.
- If the LED does not light up, the input range should be decreased.

As soon as a proper input range is found (i.e. the min. level at which the LED does not light up), it is this value should be increased by +3dB - in order to get some headroom - and stored in the unit. Alternatively, it is possible to calculate the expected bin levels of the received multitone signal. Under the assumption that the DUT has an almost flat frequency response, i.e. that then received bin levels - thereunder called *return levels* U_{return} - are almost identical, they may be calculated according to

$$U_{return(expected)}[V] = \frac{U_{mult}[V] * A}{c_f * \sqrt{n}}$$

Equation 9 Expected Return Level at Flat Frequency Response

wherein *A* is the gain of the DUT and c_f the Crest factor of the multitone signal.

Program Example

This ends the basic set-ups for a measurement sequence. The default commands are once more listed together showing a complete initialization block.

```
10   OUTPUT 703;"INPUT:FRONT ON"
20   OUTPUT 703;"OUTPUT:FLOAT ON"
30   OUTPUT 703;"INPUT:SYNC INT"
40   OUTPUT 703;"OUTPUT:MTONE:ACTIVE 1"
50   OUTPUT 703;"OUTPUT1:MUTE OFF
60   OUTPUT 703;"OUTPUT2:MUTE OFF
210  OUTPUT Adr;"input:swf off" END
240  OUTPUT Adr;"input1:range 0 dBVp" END
250  OUTPUT Adr;"input2:range 0 dBVp" END
310  OUTPUT Adr;"meas1:level:unit dBVp" END
320  OUTPUT Adr;"meas2:level:unit dBVp" END
330  OUTPUT Adr;"meas1:dist:unit dBV" END
340  OUTPUT Adr;"meas2:dist:unit dBV" END
350  OUTPUT Adr;"meas1:noise:unit dBV" END
360  OUTPUT Adr;"meas2:noise:unit dBV" END
370  OUTPUT Adr;"output:mtone:pretriggerlength   000" END
380  OUTPUT Adr;"output:mtone:mtonelength 000" END
```

Listing 3 Typical Initialization Sequence

Overview

The subsequent table provides an overview on all compulsory and optionally setable multitone burst parameter.

Parameter	*Range / Calculation*	*Remarks*
NoOfSamples (Blocklength)	512, 1024, 2048, 4096, 8192	• A large blocklength results in a higher frequency resolution but longer the signal duration • A small blocklength results in shorter signal lengths but lower frequency resolution
# of signal bins	1-31	• Set few signal bins only for distortion measurements • Many signal bins may be advantageous for level, noise, crosstalk or phase measurements
Signal bin number	$Bin\# = \frac{f_n * Blockl.}{48000}$	1. Note which frequencies f_n shall be transmitted 2. Calculate the n signal bin numbers by using f_n
Phases	-π to +π	If in doubt, distribute the phases of the signal bins statistically over the allowed range
Input Connection	Front, Rear	Make sure that the defined location corresponds with the physical connection
Float / Ground Mode	Float, Ground	• For balanced applications, use the float mode • For unbalanced applications, use the ground mode
SYNC Mode	INT, INTN, EXT	• INT is recommended for normal applications or where a time delay > 50ms for signal transmission is expected • INTN if frequency shifts occur or for analysis of non-RAPID-TEST signals or if error 203 occurs • EXT for remote applications
Pretrigger length	0-30000ms	Introduce a pretrigger for test circuits comprising an AGC module
Multitone length	0-30000ms	Prolong the multitone length for DUTs with an internal filter
Output Level	Level, Binlevel; [V], [dBV], [Vp] or [dBVp]	Adjust output level to the available headroom of the test circuit
Input Range	-60 to +20 [dBVp] or 0.001 to 10 [Vp]	Adjust input range to the max. expected input signal level

Table 5 Overview on Multitone Burst Parameter

Signal Transmission

Before a multitone burst, stored in one of the four RAPID-TEST memory locations, can be transmitted it has to be activated, i.e. selected. This must be done prior to sending off the burst, so that the "start" command does not have to comprise a signal specifier. The command for the latter is

```
OUTPUT:MTONE:ACTIVE x
```

wherein x is a number from 1 to 4. The command to immediately transmit the active multitone burst is

```
OUTPUT:MTONE:START
```

This command initiates two processes

- Send off the multitone burst through the generator
- Arm the analyzer to gather synchronously the incoming signal

If you are trying to detect the transmitted burst in the test circuit, be aware that it lasts for a couple of hundred milliseconds only. Therefore, when starting to operate a set-up it might be advisable to connect a small monitor loudspeaker to one of the outputs of RAPID-TEST in order to get an acoustical feedback of signal transmission.

Continuous Mode

To trace the multitone signal through the DUT you might program a small loop that shoots off the multitone signal repetitively until it is interrupted by a keypress. Another approach to have a continuous output from the generator is to use command

```
OUTPUT:MTONE:CONTINUOUS
```

which forces RAPID-TEST to send out the multitone burst endlessly without any header or interruption until another IEEE command is received.

NOTE **Command `OUTPUT:MTONE:CONTINUOUS` is a generator function only. RAPID-TEST is not doing any measurements during continuous mode. Nevertheless, this mode can conveniently be used to program RAPID-TEST as a single frequency or multitone signal generator that might be used for many applications as e.g. modulator tests or leveling of the DUT to adjust the input range of RAPID-TEST.**

Muted Mode

Except of the continuous mode, RAPID-TEST does not permanently send out a signal through its outputs. Instead, the generator is active only to send off the short burst. However, each of the channels can be muted individually, regardless of the set output levels. The mute command physically disconnects the output connectors from the output amplifier. To mute a channel, use command

```
OUTPUTx:MUTE y
```

wherein *x* indicates the channel (`1` or `2`) and *y* whether this channel shall be muted (`ON`) or not (`OFF`).

Has the Signal Been Received?

If both multitone burst definition & the test set-up have been done, the multitone burst should pass the DUT and appear at the analyzer inputs. In case that the quality of the transmitted signal is sufficient, the analyzer is able to sample the incoming signal and to calculate the measurement results.

In order to see whether signal transmission has been successful, please check the two LEDs labeled OVERLOAD and TRIGGER during transmission.

The OVERLOAD LED must not light up at any time during the transmission. If this happens nevertheless, the *input range* has to be increased.
However, it might also happen that the *output level* is too low. To check this, increase this value stepwise until LED OVERLOAD goes on. By this, you can find out the best output level for your specific test circuit.

The TRIGGER LED flashes, if a trigger has been recognized (except at SYNC mode INTN). If no trigger has been recognized and no overload has occurred, following points have to be checked.

Correct Wiring

In complex set-ups it might easily happen that the inputs and outputs are mixed up or that a cable is not connected. To check this, the external cabling of RAPID-TEST can be deactivated by entering the command

```
INPUT:LINK ON
```

This instruction internally links the analyzer inputs directly to the generator outputs, regardless of any external connections. Although no real measurements can be performed in this mode, it allows to verify the correctness of the controlling software and the parameter set therein.

For instance, if the TRIGGER LED goes on in this mode, it becomes clear that the burst transmission in principal is OK, however, that the signal must get lost somewhere on its way through the test circuit.

After your investigations, disable the internal link with command

```
INPUT:LINK OFF
```

Time Variances

If wiring is correct, but the multitone burst does not properly pass the DUT, it might be that the signal path inheres time variant elements (e.g. AGCs or compressors), or that a settling time of a component simply is longer than the burst duration. For instance, when working with an HP8920, the automatic gain control for constant modulation bandwidth cannot be fixed.

To overcome such problems it might be useful either to introduce a *pretrigger* or to enlarge the *multitone length* (see p. 20). To optimize these two parameter start with very high values, such as 5000. Start to reduce first the multitone length until reliability starts to decrease, and continue to minimize the pretrigger parameter the same way.

NOTE	**Whenever possible, try to set all time variant elements of the test circuit to a fix value in order to save test time.**

Changes of the Trigger Signal

It may happen that the DUT or another component of the signal path change the trigger in a way that RAPID-TEST will not be able to identify it any more. This effect typically occurs due to frequency shifts, that may be caused e.g. by modulators or tape recorders.

In this case, it is recommended to set the SYNC mode to `EXTernal`.

Querying the Measurement Results

As soon as a sent-off signal will be received properly by the analyzer, we can enter the last stage of setting up RAPID-TEST, the query of the measurement results.

After having received the multitone burst, the analyzer stores all relevant information in its memory. As soon as the user queries for a particular measurement result, the processor calculates it from the internally stored FFT vector. This procedure has two big advantages

- The user can decide whether one of the available weighting filters shall be applied on the measurement result calculation or not.
- The query for any measurement function may be repeated at any time without the need to transmit the multitone burst another time.

Following example illustrates how the software can detect whether a trigger has been received properly and how to query for the frequency response of channel 1.

Level Measurement

```
10  REM --- Measurement of frequency response of channel one ---
30  REM -------------------------------------------------------
35  DIM Rcv$[1000]
36  DIM X$[10]
37  DIM Y$[20]
38  DIM Freq(31)
39  DIM Ampl(31)
40  Fs=48000
45  REM --- Query for the multitone blocklength and name
46  OUTPUT 703;"OUTPUT:MTONE:BLOCKLENGTH?"
47  ENTER 703;Rcv$
50  Block=VAL(Rcv$)
51  OUTPUT 703;"OUTPUT:MTONE:NAME?"
52  INPUT 703;Rcv$
53  Name$=Rcv$[2,9]
60  REM --- Start the tone burst
70  OUTPUT 703;"OUTPUT:MTONE:START"
80  REM --- Define the unit for the measurement results (V rms)
85  OUTPUT 703;"MEASUREMENT1:LEVEL:UNIT V"
90  OUTPUT 703;"MEASUREMENT1:LEVEL?
95  ENTER 703;Rcv$
100 REM ---
110 REM --- Interpretation of the results returned in Rcv$
120 REM ---
130 Xpos=POS(Rcv$,"/")
140 Ypos=POS(Rcv$,",")
145 Count=0
150 WHILE (Xpos>0) AND (Ypos>0)
155   REM --- This loop is only entered if values are available
156   REM --- Interpret as: as long as there are separators do:
158   Count=Count+1
160   X$=Rcv$[1,Xpos-1]              ! isolate X value
170   Freq[Count]=VAL(X$)            ! convert X string to value A
180   Ypos=POS(Rcv$,",")             ! find Y/X separator
190   IF Ypos>0 THEN                 ! is there another value? >
200       Y$=Rcv$[Xpos+1,Ypos-1]     ! isolate Y value
210   ELSE
220       Y$=Rcv$[Xpos+1,LEN(Rcv$)] ! isolate Y value
230   END IF
240   Ampl[Count]=VAL(Y$)            ! convert Y string to value
250   Rcv$=Rcv$[Ypos+1,LEN(Rcv$)]    ! delete the raed XY pair from string
```

```
260   Xpos=POS(Rcv$,"/")              ! find next X/Y separator
280 END WHILE
290 REM--- End of string analysis
300 REM--- Check for errors
310 OUTPUT 703;"SYSTEM:ERRORS?"
320 ENTER 703;Rcv$
330 Err=Val(Rcv$)
335 IF Err>0 THEN
340 DISP"No measurement results available: ERROR occurred"
350 SELECT Err
360   CASE 201 DISP "Received data do not correlate to stored data"
370   CASE 203 DISP "Analyzer has not received a trigger"
380   CASE 210 DISP "Analyzer input overload => increase input range"
390   CASE >0 DISP "Error No. ",Err
400 END SELECT
410 ELSE
420 DISP "Measurement results are available"
425 Deltaf=Fs/Block
430 FOR I=1 TO Count
440   Freq[I]=Deltaf*Freq[I]
450   PRINT Count;" : ",Freq[I]," Hz ä,Ampl[I]," V"
460   NEXT I
470 END IF
500 END
```

Listing 4 Query for Frequency Response Measurement

⇒ At the beginning, this BASIC routine initializes the used variables.

⇒ The sampling rate is defined in line 40.

⇒ Line 45 to 48 ask the system for the blocklength of the actually selected multitone signal. These two parameter are used later for calculation of the frequencies.

⇒ For documentation purposes, lines 50 to 53 query the system for the stored name of the multitone signal that is stored in "Name$".

⇒ The program activates the transmission of the multitone signal in lines 60 to 70. Desired level adjustments would have to be inserted before this command.

⇒ Line 85 defines that we want to receive the level values in Volt RMS (of course, any other unit could be selected as well).

⇒ Right afterwards, line 90 queries for the measurement results, which we get back with the ENTER command in line 90.

⇒ The routine listed from line 100 to 280 analyzes the returned result, which is a string of ASCII characters, comprising pairs of frequency - level values. These pairs have to be separated first before further analysis. With reference to the command description in the ***User Manual*** we can find that the list of results is returned in following form

$Freq_No_1$ / $Level_1$, $Freq_No_2$ / $Level_2$, ... , $Freq_No_n$ / $Level_n$

Each frequency number is terminated with "/" while each level value is terminated with "," except the last one. The program looks in the string for the position of the "/" (Xpos) as well as

for the "," (Ypos). "Count" represents the number of measurement pairs we have found in the string. It is set to 0 before entering the analysis loop and remains 0 if no signal has been received or if the signal was in a unreadable condition. If an error occurs, i.e. if the variable "Xpos" and "Ypos" are 0, the answer string is empty and contains a "CR" character only.

NOTE	**If the string "NaN" (not a number) is returned instead of a value, the respective signal bin is too close to its neighbor. To avoid this, one may increase or decrease slightly the frequency of this signal bin.**

Line 150 is the beginning of a while loop with an entry condition. If this condition is not met the whole loop is not executed and the program resumes with line 290, the beginning of the error analysis. In any other case the loop will be executed at least once. The counter "Count" is incremented by one indicating the analysis of the first pair. A part of the string, beginning with the start and ending with the last character before the "/" is copied into the variable "X$". This string is converted into a number and stored in the array "Freq[]" as the first the value in line 170. The Y value is extracted, starting behind the "/" and ending before the ",". Here we have to make a difference as in line 190. If "Ypos" is 0, it is the last value in the row and we convert from the "/" to the end of the string. The string is again converted into a number and stored in the array "Ampl[]" in line 240. A nice effect is that the units, that are part of the conversion string, are not considered by the conversion routine, but just ignored.
Line 250 cuts the already converted part of the string away and the "Xpos" marker is set newly. The program execution resumes again at the beginning of the WHILE loop with the conditional branch. If this condition is met, the loop is executed again. If not, the error analysis at line 290 is started.

⇒ The error analysis queries for any errors. If no error has occurred, "Rcv$" contains an ASCII zero, otherwise it contains an error number in ASCII characters. The string is converted into a number and with the CASE selection the error display is performed. The more likely occurring errors are displayed with text, the rather unexpected ones with the error number only. In the absence of any error the program execution resumes at line 420 with the result presentation.

⇒ The measurement results are stored in the two arrays "Freq[]" and "Ampl[]", which are filled up to "Count". The Freq[] vector contains the bin numbers that will be converted into frequencies before being displayed while the Ampl[] vector contains the RMS levels in Volts. To convert the bin numbers into frequencies expressed in Hz, the frequency spacing is calculated. The FOR..NEXT loop (line 430 to 460) lists all measurement results in a table.

⇒ If the DUT had a 750µs emphasis weighting characteristic applied during transmission, the frequency response can be corrected even after the measurement by engaging the deemphasis filter with command

```
OUTPUT 703;"INPUT:DEEMPHASIS ON"
```

The analysis query is first passed through the filters and returned to the controller. The original data are neither changed nor deleted during this filtering. This allows to de-activate the filtering characteristics again at any time and query again for the unweighted measurement results.

Distortion Measurement

The distortion measurements can be queried almost the same way as the level measurements. The main difference is that the distortion measurement answer string contains one more pair of results than the number of defined frequencies (signal bins). The first pair contains the frequency of the first set signal bin and the distortion measurement contains the distortion energy between 20Hz and this first signal bin. The second pair defines the second frequency and the distortion energy between the first signal bin and the second signal bin etc. The last measurement result contains the frequency of the last signal bin and the distortion energy between this last signal bin and 20kHz.

NOTE **If the string "NaN" (not a number) is returned instead of a value, the respective signal bin is too close to its neighbor. To avoid this, one may increase or decrease slightly the frequency of this signal bin.**

The listing below is almost identical to the *Listing 4*, however it contains the required changes in order to obtain distortion measurements in dBV.

```
10  REM --- Measurement of distortion in channel 1 only ---
30  REM ------------------------------------------------
35  DIM Rcv$[1000]
36  DIM X$[10]
37  DIM Y$[20]
38  DIM Freq(31)
39  DIM Dist(31)
40  Fs=48000
45  REM --- Query for the multitone blocklength and name
46  OUTPUT 703;"OUTPUT:MTONE:BLOCKLENGTH?"
47  ENTER 703;Rcv$
50  Block=VAL(Rcv$)
51  OUTPUT 703;"OUTPUT:MTONE:NAME?"
52  ENTER 703;Rcv$
53  Name$=Rcv$[2,9]
60  REM --- Start the tone burst
70  OUTPUT 703;"OUTPUT:MTONE:START"
80  REM --- Define the unit for the measurement results (V rms)
85  OUTPUT 703;"MEASUREMENT1:DISTORTION:UNIT dBV"
90  OUTPUT 703;"MEASUREMENT1:DISTORTION?
95  ENTER 703;Rcv$
100 REM --- Interpretation of the results returned in Rcv$
130 Xpos=POS(Rcv$,"/")
140 Ypos=POS(Rcv$,",")
145 Count=0
150 WHILE (Xpos>0) AND (Ypos>0)
155   REM --- This loop is only entered if values are available
156   REM --- Interpret as: as long as there are separators do:
158   Count=Count+1
160   X$=Rcv$[1,Xpos-1]              ! isolate X value
170   Freq[Count]=VAL(X$)            ! convert X string to value Freq[]
180   Ypos=POS(Rcv$,",")             ! find Y/X separator
190   IF Ypos>0 THEN                 ! is there another value? >
```

```
200       Y$=Rcv$[Xpos+1,Ypos-1]     ! isolate Y value
210   ELSE
220       Y$=Rcv$[Xpos+1,LEN(Rcv$)] ! isolate Y value
230   END IF
240   Dist[Count]=VAL(Y$)            ! convert Y string to value
250   Rcv$=Rcv$[Ypos+1,LEN(Rcv$)]    ! delete the read XY pair from string
260   Xpos=POS(Rcv$,"/")             ! find next X/Y separator
280 END WHILE
290 REM--- End of string analysis
300 REM--- Check for errors
310 OUTPUT 703;"SYSTEM:ERRORS?"
320 INPUT 703;Rcv$
330 Err=Val(Rcv$)
335 IF Err>0 THEN
340   DISP "No measurement results available: ERROR occurred"
350   SELECT Err
360     CASE 201 DISP "Received data do no correlate to the data stored"
370     CASE 203 DISP "Analyzer has not received trigger"
380     CASE 210 DISP "Analyzer input overload => increase input range"
390     CASE 0 DISP "Error No: ",Err
400   END SELECT
410 ELSE
420   DISP "Measurement results are available"
425   Deltaf=Fs/Block
430   FOR I=1 TO Count
440     Freq[I]=Deltaf*Freq[I]
450     PRINT Count;" : ä,Freq[I]," Hz ä,Dist[I]," dBV"
460   NEXT I
470 END IF
500 END
```

Listing 5 Distortion Measurement

Calculation of the Total Distortion

The vector "`Dist[]`" contains all distortion values in the frequency bands between neighbored signal bins. Normally, these distortion values are more or less equal. Therefore, an increased distortion in a certain band may be a good indicator to identify a problem with the DUT.

However, for certain applications it might be of interest to know the *total distortion* or even the approximation for the conventional THD+N value (especially when stimulating the DUT with a single frequency). The procedure to get this value shall be described below.

First, for comparability reasons, it is advisable to query the single distortion values D_n always expressed in Volt RMS. This allows calculation of the *total distortion* (TD) value.

$$TD[V] = \sqrt{D_1[V]^2 + D_2[V]^2 + \ldots + D_n[V]^2 + D_{n+1}[V]^2}$$

Equation 10 Total Distortion TD

wherein *n* is the number of defined frequencies (signal bins). Please notice that with above formula, the single distortion values have to be present in linear scale [V] and not in [dBV].

In order to get the *total signal level*, the energies can be summed up almost identically by using the single level values S_n, expressed in Volt RMS.

$$Signal[V] = \sqrt{S_1[V]^2 + S_2[V]^2 + ... + S_n[V]^2}$$

Equation 11 Total Signal Level

As soon as we know these two values, it becomes possible to calculate a value, herein called *MT-SINAD*, that is comparable to the SINAD.

$$MT\text{-}SINAD[\%] = 100 * \frac{Signal[V] + TD[V]}{TD[V]} \quad \text{or} \quad MT\text{-}SINAD[dB] = 20 * \log_{10}\left(\frac{Signal[V] + TD[V]}{TD[V]}\right)$$

Equation 12 Multitone SINAD (MT-SINAD)

NOTE **Newer RAPID-TEST units allow to directly query the MT-SINAD value. Please refer to the corresponding *User Manual*.**

Noise Measurement

Noise measurements can be obtained exactly the same way and with the same program as listed in *Listing 5*. The only necessary changes concern the measurement result query command in lines 85 and 90 that have to be replaced against

```
85 OUTPUT 703;"MEASUREMENT1:NOISE:UNIT dBV"
90 OUTPUT 703;"MEASUREMENT1:NOISE?
```

and replacement of variable "`Dist[]`" by "`Noise[]`". The handling and building of a total noise value is absolutely identical as of a distortion.

Phase Measurement

The phase shift caused by a DUT typically varies in its value depending on the stimulating frequency. For this reason it is recommended to set a larger number of signal bins, in order not to omit any dramatic change.

To evaluate the phase shifts of the signal bins of a transmitted multitone use command

```
MEASUREMENTx:PHASE?
```

wherein *x* indicates the channel number of interest. The returned answer is a string that contains pairs of `BinNumber/PhaseShift` values, separated by commas (`,`).

Crosstalk Measurement

For evaluation of the crosstalk, it is important to know that this broad-band effect usually happens at higher frequencies, where it is also most annoying. Obviously, it is vital to set the signal bins at different frequencies in channel 1 and 2 of a multitone signal. Only by this means it becomes possible to measure the crosstalk from channel 1 to channel 2 and vice versa.

The command to query the crosstalk is

```
MEASUREMENTx:CROSSTALK?
```

wherein *x* indicates the channel number of interest. The returned answer is a string that contains pairs of `BinNumber/Crosstalk` values, separated by commas (,).

Rapid-Test Commander

During evaluation and testing RAPID-TEST it is very awkward and time consuming always to enter the BASIC instruction "`OUTPUT 703`", which is necessary to send commands to or query answers or errors from the unit.

For this purpose, the short BASIC program listed below was written. It asks the user on the screen to enter a RAPID-TEST command, completes it and sends it down to the instrument, queries for possible errors and displays them. In case that the entered command was a query, i.e. a command ending with a "?", the answer is immediately read up and displayed.

```
10  Adr=703
20  DIM Cmd$[100]
30  DIM Rcv$[100]
40  INPUT "Command: ",Cmd$
41  PRINT "Cmd: ";Cmd$;
42  OUTPUT Adr;Cmd$ END
45  IF Cmd$[LEN(Cmd$)-1]="?" THEN
46    ENTER Adr;Rcv$
47    PRINT "  Answer: ";Rcv$;
48   END IF
50  OUTPUT Adr;"SYSTEM:ERRORS?" END
60  ENTER Adr;Rcv$
70  Err=VAL(Rcv$)
80  SELECT Err
90    CASE 0
100     PRINT "   No error"
110   CASE ELSE
120     PRINT "  *** Error No: ";Err
130 END SELECT
140 GOTO 10
150 END
```

Complete Measurement Program

Finally, after having explained and shown the use of the most important RAPID-TEST commands, an entire BASIC program is listed below to allow to perform complete measurements with RAPID-TEST. It uses most of the previously explained routines and sequentially measures all available audio parameter of both channels. The results are displayed in a table as well as in a bargraph display.

```
10    REM -----------------------------
11    REM --- Rapidtest Demo Program ---
12    REM -----------------------------
20    DIM Message$[100]
30    MERGE ALPHA WITH GRAPHICS
40    GINIT
50    CLEAR SCREEN
60    Measnr=0
70    !*****************************************************************
80    !*****************************************************************
90    Adr=3              !Enter IEEE Address here
100   A2=703             !Enter IEEE Address here
110   !*****************************************************************
120   !*****************************************************************
130   Adr=Adr+700   ! evaluate Output/Enter Address
140   CLEAR Adr
141   OUTPUT Adr;"output1:level -6 dbVp" END
142   OUTPUT Adr;"output2:level -6 dbVp" END
143   OUTPUT Adr;"outp:float off" END
145   OUTPUT Adr;"output:mtone:active 1" END
160   !***************** INITIALIZE ***********************************
180   OUTPUT Adr;"input:sync int" END
190   OUTPUT Adr;"input:link on" END
200   OUTPUT Adr;"input:front on " END
210   OUTPUT Adr;"input:swf off" END
240   OUTPUT Adr;"input1:range 0 dBVp" END
250   OUTPUT Adr;"input2:range 0 dbVp" END
260   OUTPUT Adr;"outp:float on" END
270   OUTPUT Adr;"output1:mute off" END
280   OUTPUT Adr;"output2:mute off" END
310   OUTPUT Adr;"meas1:level:unit dbVp" END
320   OUTPUT Adr;"meas2:level:unit dbVp" END
330   OUTPUT Adr;"meas1:dist:unit dBV" END
340   OUTPUT Adr;"meas2:dist:unit dBV" END
350   OUTPUT Adr;"meas1:noise:unit dBV" END
360   OUTPUT Adr;"meas2:noise:unit dBV" END
370   OUTPUT Adr;"output:mtone:pretriggerlength   000" END
380   OUTPUT Adr;"output:mtone:mtonelength 000" END
390   !*****************************************************************
400   GOSUB 890     ! Read system information
410   WAIT 1.5
420   !Measurement Loop
430   Measnr=Measnr+1
440   OUTPUT Adr;"Output:MTone:Start " END
```

```
450   WAIT 0!-----------------------------------
460   OUTPUT Adr;"Measurement1:level?" END    !Terminate Output with END
470   Message$="Amplitude plot 1 "
480   GOSUB 1200         !Read the measurements
490   GOSUB 830          !Read Errors
500   !-----------------
510   OUTPUT Adr;"Measurement1:dist?" END     !Terminate Output with END
520   Message$="Distortion plot 1 "
530   GOSUB 1200         !Read the measurements
540   GOSUB 830          !Read Errors
550   !-----------------
560   OUTPUT Adr;"Measurement1:noise?" END   !Terminate Output with END
570   Message$="Noise plot 1 "
580   GOSUB 1200         !Read the measurements
590   GOSUB 830          !Read Errors
600   !-----------------
610   ! GOTO 420    ! FOR 1 - Channel measurement only
620   !-----------------
630   OUTPUT Adr;"Measurement2:lev?" END !Terminate Output with END
640   Message$="Amplitude plot 2 "
650   GOSUB 1200         !Read the measurements
660   GOSUB 830          !Read Errors
670   !-----------------
680   OUTPUT Adr;"Measurement2:dist?" END     !Terminate Output with END
690   Message$="Distortion plot 2 "
700   GOSUB 1200         !Read the measurements
710   GOSUB 830          !Read Errors
720   !-----------------
730   OUTPUT Adr;"Measurement2:noise?" END    !Terminate Output with END
740   Message$="Noise plot 2 "
750   GOSUB 1200         !Read the measurements
760   GOSUB 830          !Read Errors
770   !-----------------
780   GOTO 420           ! ENDLESS LOOP
790   STOP
800   !
810   ! ** SUBPROGRAMS **
820   !
830   ! Read System ERRORS
840   DIM Err$[1000]
850   OUTPUT Adr;"System:Errors?" END
860   ENTER Adr;Err$
870   IF Err$<>"0" THEN PRINT "Error(s) occured : ",Err$
880   RETURN
890   ! Read System Information
900   DIM Inf$[100]
905   PRINT
910   OUTPUT Adr;"System:Information?" END
920   ENTER Adr;Inf$
930   PRINT "System      : ";Inf$
935   PRINT
940   OUTPUT Adr;"Output1:status?" END
```

```
950   ENTER Adr;Inf$
960   PRINT "Output 1     : ";Inf$
970   OUTPUT Adr;"Output2:status?" END
980   ENTER Adr;Inf$
990   PRINT "Output 2     : ";Inf$
1000  OUTPUT Adr;"Input1:status?" END
1010  ENTER Adr;Inf$
1020  PRINT "Input  1     : ";Inf$
1030  OUTPUT Adr;"Input2:status?" END
1040  ENTER Adr;Inf$
1050  PRINT "Input  2     : ";Inf$
1055  PRINT
1060  OUTPUT Adr;"Output:mtone:name?" END
1070  ENTER Adr;Inf$
1080  PRINT "MT Name      : ";Inf$
1090  OUTPUT Adr;"output:mtone:blocklength? " END
1100  ENTER Adr;Inf$
1110  PRINT "Blocklength : ";Inf$
1120  Blocklength=VAL(Inf$)
1130  OUTPUT Adr;"output1:mtone:crest?" END
1140  ENTER Adr;Inf$
1150  PRINT "MT 1 Crest   : ";Inf$
1160  OUTPUT Adr;"output2:mtone:crest?" END
1170  ENTER Adr;Inf$
1180  PRINT "MT 2 Crest   : ";Inf$
1190  RETURN
1200  !Interpret incoming data stream
1210  DIM Rcv$[2000]
1220  DIM X$[30]
1230  DIM X(31)
1240  DIM Y$[30]
1250  DIM Y(31)
1260  Ind=0                                ! Set Index 0
1270  ENTER Adr;Rcv$                       ! Read data
1280  Xpos=POS(Rcv$,"/")                   ! Find X/Y Seperator
1290  Ypos=POS(Rcv$,",")                   ! Find Y/X Seperator
1300  !
1310  WHILE (Xpos>0) AND (Ypos>0)    ! At the presenece of Seperators do:
1320  X$=Rcv$[1,Xpos-1]                    ! Isolate X value
1330  X(Ind)=VAL(X$)                       ! convert X String to value
1340  Ypos=POS(Rcv$,",")                   ! Find Y/X Seperator
1350  IF Ypos>0 THEN                       ! Is there another value?
1360              Y$=Rcv$[Xpos+1,Ypos-1] ! Isolate Y value
1370            ELSE
1380              Y$=Rcv$[Xpos+1,LEN(Rcv$)]    ! Isolate Y value
1390            END IF
1400  IF Y$[1,3]<>"NAN" THEN Y(Ind)=VAL(Y$)
1410  Rcv$=Rcv$[Ypos+1,LEN(Rcv$)]
1411  ! Delete the read XY data pair in the received string
1420  Xpos=POS(Rcv$,"/")                   ! Find next X/Y Seperator
1430  IF Y$[1,3]<>"NAN" THEN Ind=Ind+1
1440  END WHILE
```

```
1450  CLEAR SCREEN
1460 !PRINT
1470  PRINT "           ***** ";Message$;" ";Measnr;" *****"
1480 !PRINT
1490 !PRINT
1500 !PRINT
1510  !
1520  FOR J=0 TO Ind-1              ! Write measurement arrays to screen
1530  Gx=X(J)
1540  Gy=Y(J)
1550  Rms=Rms+10^(Gy/20)
1560  PRINT CINT(2.205E+4/(Blocklength/2)*Gx),(CINT(Gy*10)/10)
1570  WAIT 0
1580  GOSUB 1620        ! Draw Bins
1590  NEXT J
1600 !PRINT "RMS  : ",20*LGT(Rms)
1610  RETURN
1620  ! Draw Bins
1630  Bottom=10
1640  Top=90
1650  Right=(100-5)*RATIO
1660  Left=25
1670  Binmax=LGT(1024)
1680  Valmax=0
1690  Valmin=-140
1700  MOVE Left,Bottom
1710  DRAW Right,Bottom
1720  MOVE Left,Top
1730  DRAW Right,Top
1740  Px=(LGT(Gx)/Binmax)*(Right-Left)+Left
1750  Py=(1+Gy/(Valmax-Valmin))*(Top-Bottom)
1760  MOVE Px,Bottom
1770  RECTANGLE .5,Py,FILL
1780  RETURN
1790  END
```

APPENDIX

Default Multitone Signals of RAPID-TEST

Signal #1

```
Output:mtone:parameter 1,'3_TONE',512,3,3,3,11,32,3,11,32,-2.85261E+00,
  -5.10121E-01,-2.27643E+00,-2.85261E+00,-5.10121E-01,-2.27643E+00
```

Signal #2

```
Output:mtone:parameter 2,'SINE1K',512,1,1,11,11,0.000E00,0.000E00
```

Signal #3

```
Output:mtone:parameter
  3,'3_TONE',2048,3,3,13,43,128,13,43,128,1.67685E+00,1.55774E-01,
  1.74544E+00,1.67685E+00,1.55774E-01,1.74544E+00
```

Signal #4

```
Output:mtone:parameter
  4,'29_TONE',8192,29,29,4,6,8,10,13,16,20,25,32,40,51,64,81,102,128,
  161,203,256,323,406,512,645,813,1024,1290,1625,2048,2580,3251,4,6,8,
  10,13,16,20,25,32,40,51,64,81,102,128,161,203,256,323,406,512,645,813,
  1024,1290,1625,2048,2580,3251,-3.01188E+00,-3.08393E+00,-5.67685E-01,
  2.30293E+00,8.71918E-01,-9.40946E-01,-2.54659E+00,1.05247E-01,
  -1.28570E+00,-1.64479E-01,1.67759E+00,-2.13891E-01,-2.29533E+00,
  -3.23547E-01,7.10806E-01,5.93797E-01,-1.67948E+00,-2.46260E+00,
  2.80533E+00,2.78002E+00,-4.92011E-01,-1.18525E+00,-2.46340E+00,
  -2.41605E+00,3.05253E+00,-1.84116E+00,-3.05858E+00,-1.45471E+00,
  3.81575E-01,-3.01188E+00,-3.08393E+00,-5.67685E-01,2.30293E+00,
  8.71918E-01,-9.40946E-01,-2.54659E+00,1.05247E-01,-1.28570E+00,
  -1.64479E-01,1.67759E+00,-2.13891E-01,-2.29533E+00,-3.23547E-01,
  7.10806E-01,5.93797E-01,-1.67948E+00,-2.46260E+00,2.80533E+00,
  2.78002E+00,-4.92011E-01,-1.18525E+00,-2.46340E+00,-2.41605E+00,
  3.05253E+00,-1.84116E+00,-3.05858E+00,-1.45471E+00,3.81575E-01
```

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Application Note

A2 • RT-1M

Comparing Conventional vs. Multitone Testing

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ABSTRACT

Most of us are familiar with conventional (i.e. sequential) audio testing. We know the troubles and the possible sources for measurement failures. But by having accepted and applied the rules of how to measure an audio parameter for a long time, we even may have forgotten its limitations and drawbacks.

In contrast to this well known path, the new approach of multitone testing may puzzle us first. But fortunately, it is as simple as the standard way of measuring, as soon as we have understood the basic principles behind this technique. Multitone testing of course has its own limitations, but also some important advantages in comparison to the conventional approach with its single sine wave stimulus.

This application note describes the basic principles of conventional and multitone testing. It explains, in which terms these two measuring methods may be compared against each other. We will understand, that a direct (mathematical) relation between the acquired results does not always exist. However, it is shown that at least in qualitative terms, the measurement results may be compared, thus allowing to establish similar Good/No-Good criteria for both approaches. Finally, the most important difference between both methods is pointed out, the *overall test duration* for a certain number of measurements.

This document was written for new users of RAPID-TEST, who are not yet acquainted with the differences between conventional or multitone testing.

Assumptions

Although the subsequent investigations and statements refer to A2/A2-D and RAPID-TEST, they are also valid for all similar test instruments, since the physics to be considered is always identical.

Furthermore, this application note has been restricted to the most basic aspects of conventional and multitone testing, since a concise survey could fill dozens of heavy folders about this topic.

Finally, this note deals with the five core audio measurement functions only, i.e. Level, Distortion, Noise, Phase and Crosstalk, as well as the required overall time duration of a measurement.

FUNDAMENTALS

This chapter explains the basics of audio analysis, particularly the two topics of this application note, i.e. single- and multitone testing. Furthermore, a summary on the most important selection criteria is given, providing helpful information about the optimum test method to be used for any specific application.

Audio Signal Analysis

Most audio signal measurements are performed by stimulating the device to be tested with a test signal and analyzing the transmitted signal as soon as it has passed the device. One must be aware that the result of this evaluation consists of a few core quantities only, all of them relating to the capabilities of the human hearing sense.

- The most commonly used parameter is *Level*. Normally, it indicates the complete energy content of the signal, expressed as RMS value. Alternatively, by using a narrow bandpass filter, the *Level Selective* value results, considering the energy of a small band around the fundamental signal frequency only.
- Both the *Harmonic Distortion* (*THD+N* or *SINAD*) and *Intermodulation Distortion* (*IMD*) test refer to new signal components (i.e. frequencies) that are generated by the DUT. To measure them, the fundamental signal must be suppressed by using a narrow-band rejection filter, so that the new components come through only.
- The *Noise* measurement is normally done with a quasi-peak detector, measuring those audible components (spikes) of the incoming signal, which will not appear in the Level result due to their low energy contents.
- *Phase* and *Crosstalk* are important for the characterizations of dual-channel devices in order to identify the differences between the two channels.

Keep in mind, that there is one more property to be considered for any kind of measurement, the*time* (or *group*) *delay* of the signal on its way through the DUT. This parameter indicates the time passing between the moment the test signal has been sent by a generator and the time when the analyzer has received it.

Conventional Measurements

In practice, most audio tests are based on the use of a sine signal with one specific frequency.

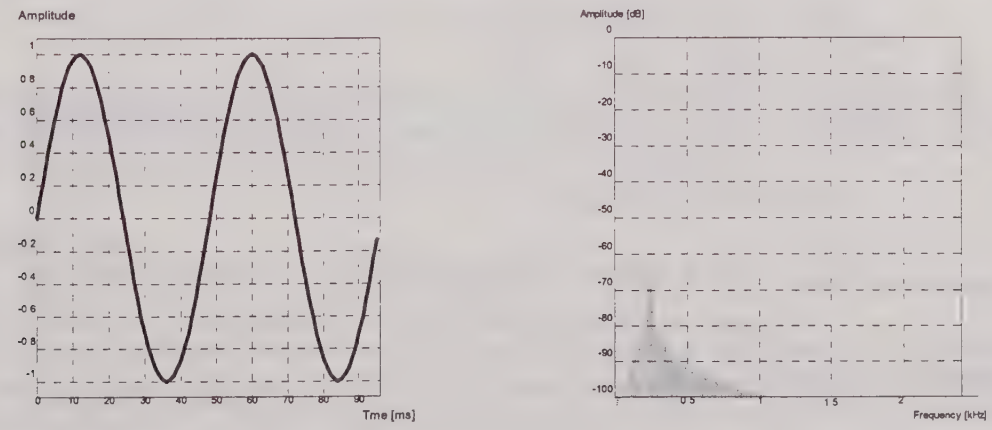

Fig 1 Time Plot & Spectrum of Single Tone Signal

In order to get a characterization over the complete frequency range, the generated signal must be swept through the band of interest, i.e. its frequency has to be increased (or decreased) stepwise, while at every step a measurement is executed.

For instance, the frequency response of a DUT in the audio range can be evaluated with a single tone test signal starting at 20Hz and ending at 20kHz, with a user-defined number of steps in between.

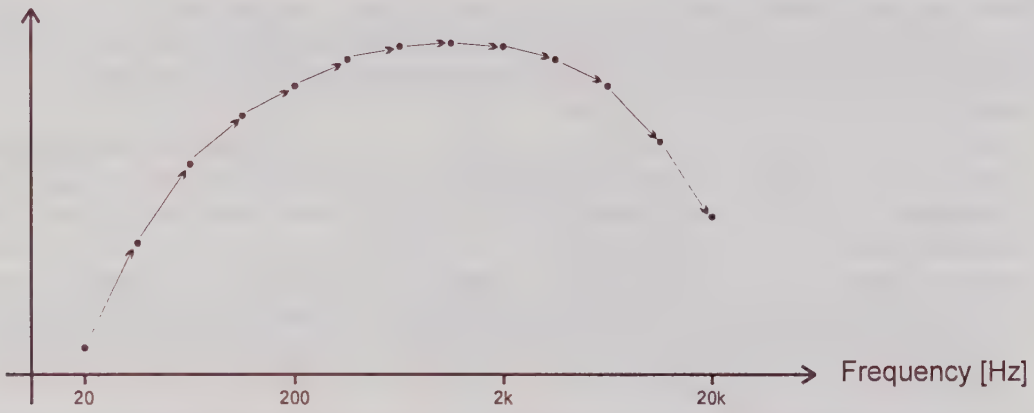

Fig 2 Example of Single-Tone Level Sweep over 13 Frequencies

Multitone T

In contrast tc ; transmission
of several sir rises not only
one, but diffe

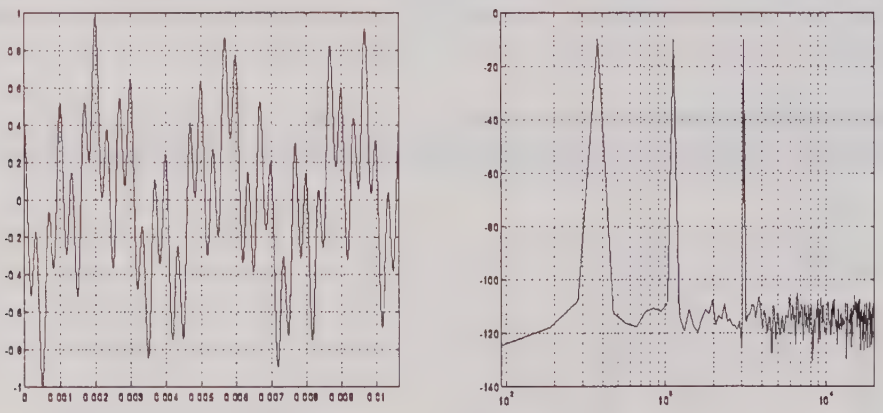

Fig 3 Time Plot & Spectrum of a Multitone Signal with 3 Frequencies (Signal Bins)

The level plot of a multitone analysis corresponds to the received amplitude values at the defined frequencies of the received signal.

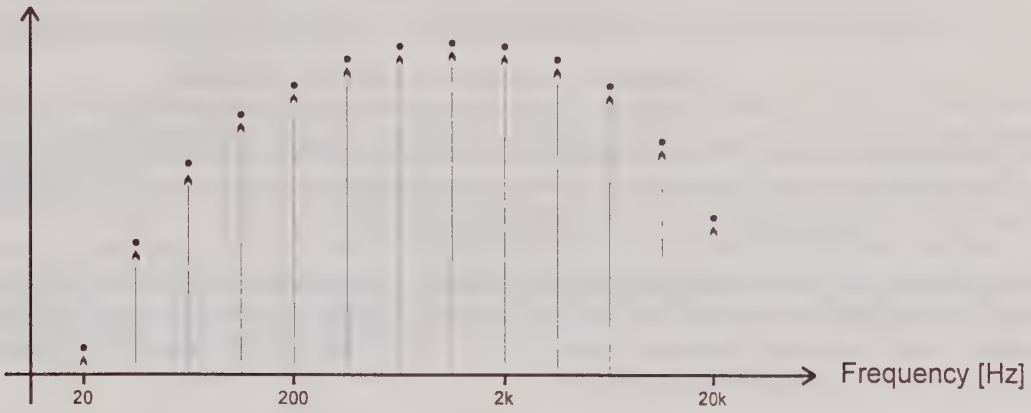

Fig 4 Example of 13-Bin Multitone Level Plot

Alternatively, the principle of a multitone test, providing five measurement results, all acquired in parallel at a time, may be described by following picture.

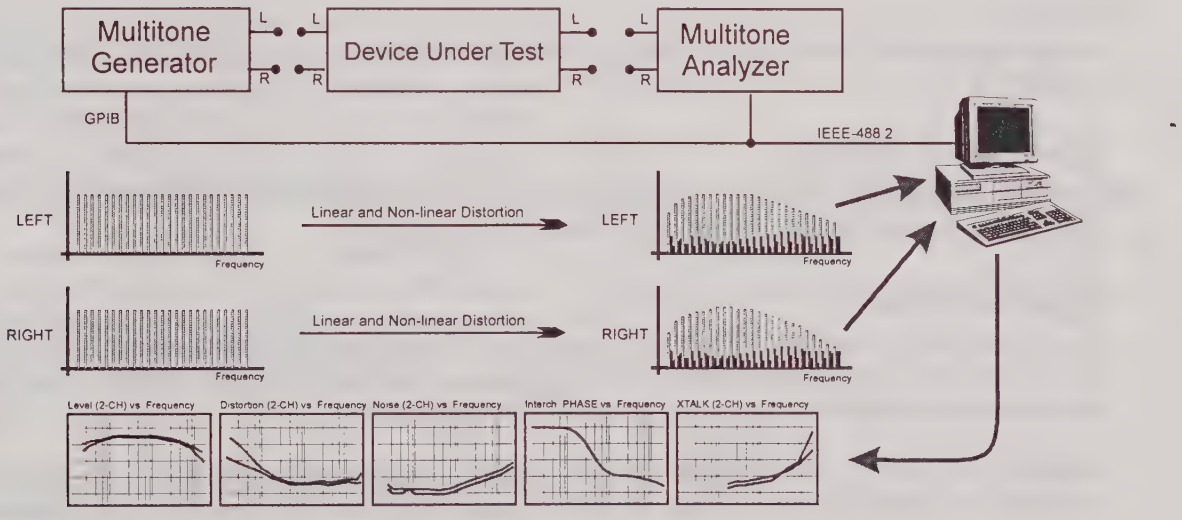

Fig 5 Multitone Test Principle

The multitone burst is transmitted through the DUT to the analyzer. The latter extracts the raw data by FFT analysis out of the received time signal and uploads them to the controlling device. The PC then allows to calculate and to display the different audio parameter plots.

Bins & Signal Bins

Before we start to discuss the multitone technique, it is vital to understand some basics of digital signal generation and especially the meaning of two terms, *bin* and *signal bin*.

First, a discretely generated time signal of limited length can comprise certain frequencies only. These frequencies f_n are given by the *blocklength*, i.e. the number of samples which build the signal, as well as the sampling frequency f_s.

$$f_n = n * \frac{f_s}{blocklength} \quad \text{with } n = 1, 2, 3, \ldots$$

Equation 1 Possible Frequencies of a Time Signal

In the multitone world, these possible frequencies have been named *bins*. However, a practical multitone signal will almost never comprise all possible frequencies, but a user-defined selection of them only. These actually set bins are called *signal bins*.

Furthermore, the bins and signal bins are normally not described by their frequencies, expressed in Hertz, but instead by their *bin number*. This value is obtained by numbering all possible frequencies starting with the lowest possible value (0Hz, i.e. DC, with the bin number 0). Alternatively, the bin numbers can be calculated according to

$$BinNo = \frac{Blocklength * f_n}{f_s}$$

Equation 2 Bin Number Calculation

Example

At a blocklength of 1024 and a sampling rate of 48kHz, the frequency of 562.5Hz corresponds to bin number 12.

Application Criteria

This chapter deals with the main characteristics of the two measurement principles, in order to support the user to choose the best approach for the actual application.

Signal Definition

The signal definition with RAPID-TEST is easy - you simply choose the frequencies you are interested in, by selecting the corresponding bin numbers. Consequently, after signal transmission, the instrument returns the measured results at all these frequencies.

However, depending on the DUT and the required measurement function, one normally has to optimize some characteristics of the multitone signal, as e.g. its level, frequencies and phases.

Bandwidth

The available frequency range of the transmission path always has to be considered. It is defined by the minimum and maximum frequency which can pass through the DUT. For instance, it would be useless to investigate telecom devices such as cellular phones - typically providing a bandwidth of 300Hz to 3kHz - with a test signal of 20kHz.

Number of Samples

The analysis of every audio parameter has to be optimized by the appropriate choice of the test signal(s). For instance, a detailed frequency response requires more frequencies to be measured than a crosstalk test, where few frequencies in the higher frequency range are of interest only.

Number of Signal Bins

The question about the optimum number of signal bins to be set for a certain test depends on several parameter.

- In most industrial applications, it is necessary to check a few 3 to 5 selected core frequencies only. Usually, this already allows a Good / No-Good decision, providing enough security that all faulty samples are found.
- From another point of view, one may take into account the specific demands of the different measurement functions. The level and phase measurement may require a larger number of signal bins in order to get a precise representation of the frequency and phase response. On the other hand, the distortion, noise and crosstalk test should be restricted to a few signal bins only, resulting in more meaningful measurement values.

Crest Factor

When measuring a DUT with a test signal of e.g. $5V_{RMS}$, we usually don't think about the peak value of the signal, since we are used to have enough headroom (e.g. twice the signal level, i.e. 10V). This makes sense when we remember that the peak level of a sine wave equals approximately 1.41 times its RMS value ($5V_{RMS} = 7.07V_p$).

However, things are different when working with (multitone) signals that are put together by two or more sine waves with different frequencies. In such cases, the resulting time signal, which is obtained by adding its components, will show a much larger difference between its RMS and peak value.

This effect is shown in ***Fig 6***, where three sine waves with $5V_p$ have been added to a new. signal. The peak value of this new signal is 3 times as high compared to the single sine waves, while its RMS value differs by a factor of 1.73 only vs. the single curves!

The problem of a high signal peak value is that we need more headroom. For instance, the shown 3-bin signal would need somewhat like $20V_p$!

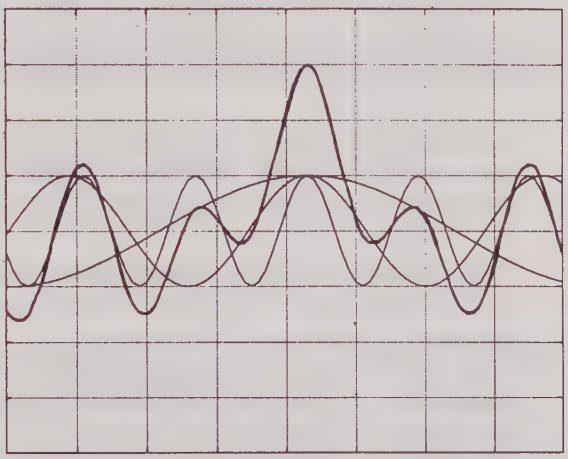

Fig 6 3-bin Signal @ 5V / Div.

Fortunately, by optimizing the phase relations between the three signals, one may end up with a much smaller peak level of the multitone signal (see below).

In order to allow the characterization of a signal, a relationship between its peak and its RMS level had to be established, the so-called Crest factor C_f. It indicates the ratio of the peak level of the signal to its RMS level. Consequently, a high Crest factor corresponds to a signal having a high peak voltage compared to the average signal level.

$$C_f = \frac{V_p}{V_{RMS}}$$

Equation 3 Crest Factor Calculation

A single sine wave has a Crest factor of $\sqrt{2}$ = 1.41. Consequently, no measures have to be taken concerning the Crest factor when working with conventional test methods.

On the other hand, different multitone signals have different Crest factors, depending on the number of signal bins and the phase relations between them. For instance, the Crest factor of a multitone signal with 31 signal bins may vary in the range from ≥ 2 to almost 8, depending on the chosen phase relations only.

Furthermore, it is vital to know that the higher the Crest factor of a multitone signal, the poorer the signal-to-noise ratio of the measurement. This can be explained easily when considering the shape of a multitone signal with a high Crest factor, i.e. a bad phase selection.

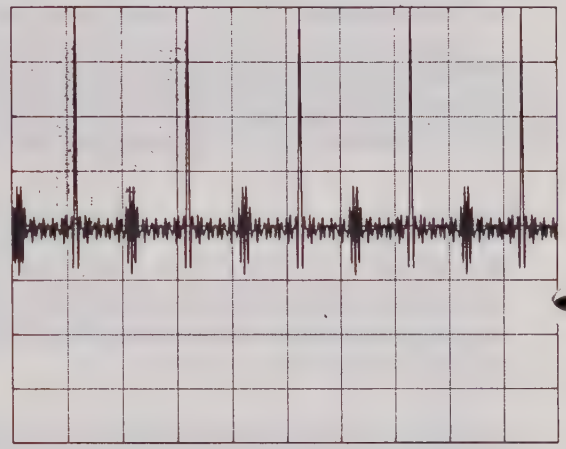

Fig 7 Multitone Signal with High Crest Factor

As you can see, the peak value of the signal is far above its average (RMS) level. Obviously, when transmitting such a signal through a DUT, one must adapt the peak voltage of the signal to the max. allowable voltage of the DUT in order to avoid clipping. Consequently, the RMS voltage of the signal becomes very small, thus coming closer to the noise floor of the transmitted signal.

So let's have a look on the same multitone signal, but this time with optimized phase relations between its signal bins, displayed in ***Fig 8***.

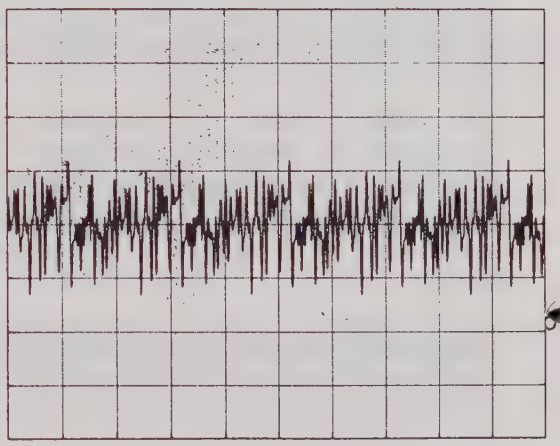

Fig 8 Multitone Signal with Low Crest Factor

This time, the difference between the peak voltage of the signal and its RMS level has become much smaller.
This does not only reduce the necessary headroom for signal transmission, but also improves the signal-to-noise ratio by far.

At this point it may be of special interest for the user to know that NEUTRIK provides an unique tool for the Crest factor optimization of a multitone signal. This feature is part of RT-EVAL, the evaluation software package for an easy access to RAPID-TEST. Please contact your local NEUTRIK representative to get your copy.

Correlation to Real-World Signals

One important question about audio measurements concerns the correlation between the acquired results and the behavior of the DUT under real-world conditions. For instance, one could argue that a DUT being stimulated with a single frequency only, may behave differently as soon as a mixture of several frequencies is applied.

In practice, this topic nowadays becomes increasingly interesting with the fast growing number of audio equipment using data reduction techniques as e.g. CODECs. These modules transmit the

audible components of a signal only by using masking effects corresponding to the human ear perception characteristics (see RAPID-TEST application note *Cellular Phone Testing*).

From this point of view, all measurement principles basing on a single sine tone transmission suffer under the drawback of a poor correlation to human speech, music or similar signals.
On the other hand, the demand for a good correlation between the test signals and real-world conditions imply the application of multitone or similar testing techniques.

Overall Test Duration

Depending on the actual application, the required time for a complete measurement might be a critical factor. For instance, for high-volume production the test duration must be kept as short as possible.

In order to evaluate the overall test duration, i.e. the time between sending off the test signal and receiving it back, a couple of influencing factors have to be considered.

- The *number of measurement functions* to be acquired.
- The *number of measurements*. Obviously, a test comprising several single measurements which are executed one after the other, proportionally prolongs the overall test duration.
- The *group delay*. This parameter indicates the time it takes for a signal to pass through the whole signal path. Please notice that in some cases, the value for the group delay varies with the frequency of the test signal.
- The *signal duration*. This parameter is given by the longest period length occurring in the test signal as well as the minimum settling time of the DUT.

Consequently, following rough approximation for the complete test duration may be given.

$$t_d = NoOfFunc * NoOfMeas * (t_{group} + t_{signal})$$

Equation 4 Overall Test Duration

With t_d = overall test duration, *NoOfFunc* = number of measurement functions, *NoOfMeas* = number of measurements, t_{group} = average group delay and t_{signal} = average signal duration.

Applied on the two approaches, it can be said that both the group delay and the signal duration are almost constant, thus providing no possibility to reduce the overall test duration. Consequently, it is the number of audio parameter and the number of measurements which allow to influence this parameter.

- With the conventional approach, the number of measurements equals the number of steps in a sweep. This means, that the higher the required resolution of a sweep is, the longer the whole measurement takes. Additionally, for each different audio parameter, the complete procedure has to be repeated.
- On the other side, a multitone burst ideally has to be transmitted once only. Furthermore, the multitone approach enables the analysis of several audio parameter at a time after having transmitted a single multitone test signal. In other terms, the values for both *NoOfFunc* and *NoOfMeas* always equal 1.

Fig 9 shows the typical overall test duration, acquired with a single tone stimulus. For this graphic, it has been assumed that a single measurement needs approx. half a second, and that for the acquisition of several audio parameters at identical frequencies, an automated remote control

software has been used. In practice, i.e. under the control of a human operator, the values would become even larger.

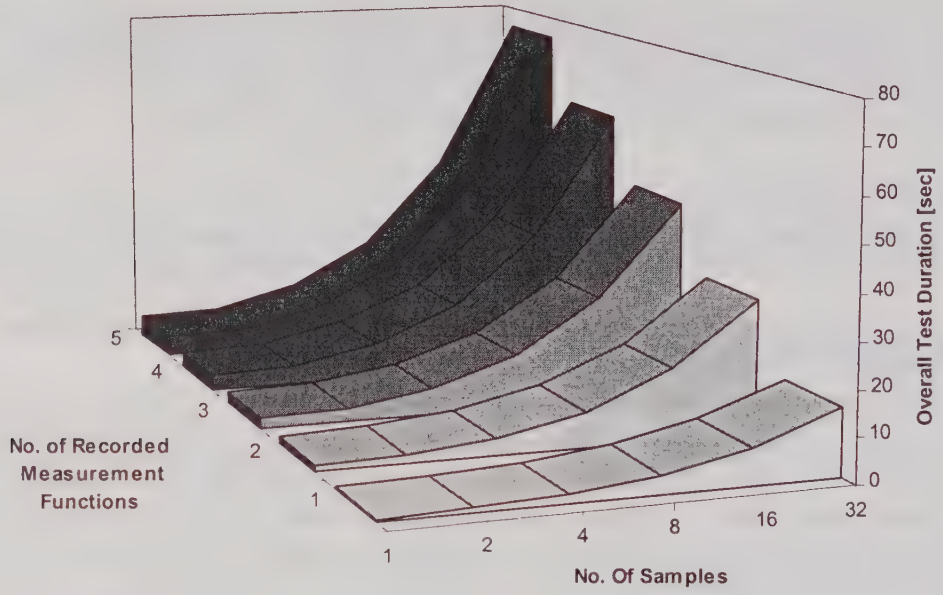

Fig 9 Typical Overall Test Duration for Conventional Measurements

On the other hand, the *overall test duration* of a multitone acquisition would typically last *1 second* only, regardless of the number of samples or recorded measurement functions.

Result Acquisition & Interpretation

One of the most important craters when comparing conventional vs. multitone measurement techniques is the interpretation of the acquired results. For instance, a service technician working in the field, wants to get results which can be understood immediately and compared easily with other values. On the other hand, in an automated environment, where well-defined tests are repeated thousands of times, it is no obstacle when the acquired results must be considered more thoroughly.

Conventional Approach

As long as the DUT is stimulated with a single sine wave only, the interpretation of the recorded measurement results is straightforward.

- The ratio between the sent-out signal level and the received one at the same frequency, directly corresponds to the attenuation / amplification factor of the DUT.
- The received distortion (THD, SINAD), i.e. those signal components, which have a different frequency as the one of the transmitted signal, are caused by the DUT or the transmission line.
- The same conclusion is valid for noise, phase and crosstalk measurements, supposed that the generator provides a sufficiently 'clean' sine signal.

Multitone Approach

The interpretation of measurement results acquired from a multitone burst transmission is as easy as with the conventional approach.

- In the Level mode, just the amplitude of the signal bins is measured,
- for Distortion and Noise analysis, certain bin levels between the signal bins are added up,
- the Phase result is obtained by comparing the signal bins on both channels, and
- for Crosstalk analysis the impact of the signal bins onto the other channel is investigated.

However, as soon as we have to cope with a DUT producing nonlinear distortion, the situation changes a little. Due to the intermodulation products, caused by these nonlinearities, it becomes impossible to evaluate the origin of any received (signal) bin level. Therefore, the interpretation of the results is not always as straightforward as we are used from the conventional method.

Fortunately, this does not compromise the meaningfulness of multitone measurement results, as it will be shown in chapter *Measurement Functions* (see page *14*).

Pros & Cons

	Single Tone	Multitone
Signal definition	👍 **simple**	☞ requires some knowledge
Correlation to real-world signals	👎 poor	👍 **good**
Test duration	☞ Increasing with number of measurements	👍 **Independent from number of measurements**
Interpretation of results	👍 **easy**	☞ requires some knowledge

Table 1 Pros & Cons

This first overview about the characteristics of the two measurement principles unveils their typical applications.

- Conventional (single tone) tests are mainly used for applications where an easy and well-known interpretation of the results is required, and where time is not the limiting factor of the test.
- Multitone measurements play a major roll at all applications where a high test speed is of prime importance.

MEASUREMENT FUNCTIONS

The subsequent chapters describe the different aspects of conventional vs. multitone testing applied on the five most commonly used audio measurements - Level, Distortion, Noise, Phase and Crosstalk.

Level

The frequency response of a DUT, i.e. the extent by which every transmitted signal component is attenuated or amplified, is one of the most important characteristics of any audio equipment. Fortunately, it is measurable in an easy way, and allows a rather straightforward interpretation of the acquired results.

With a conventional equipment, one simply has to move (sweep) the frequency of the stimulating signal through the band of interest.
On the analyzer side, the incoming signal may be either measured as broadband input level or as selectively, i.e. after being fed through a narrow bandpass filter. In the latter case, noise, which has been introduced in the test circuit, will be eliminated. Anyway, the characteristic of the results will be almost identical in most applications.

Similarly to the level selective mode, a multitone test instrument will extract the received signal level for every signal bin (frequency) of the transmitted test signal. The only thing we have to keep in mind is the possibility, that due to nonlinearities of the DUT some intermodulation products might fall onto the signal bins, too. Fortunately, even if this effect happens, its impact can be neglected in almost all cases.
Consequently, in most cases a multitone test will provide identical results as a conventionally acquired measurement.

Distortion

In opposition to the level measurement, the distortion or THD+N characteristic of a DUT normally looks very different depending on the used test method. To understand this, it is necessary to have a closer look at the two different approaches.

In a conventional test instrument, the distortion result will be measured by notching out the signal level at the sent-out (i.e. fundamental) frequency with a narrow-band rejection filter. All remaining signal components, i.e. the harmonic distortion and the noise are added up, thus building the THD+N value.

$$THD+N = \frac{U_{Distortion+Noise}}{U_{Signal+Distortion+Noise}}$$

Equation 5 THD+N Definition

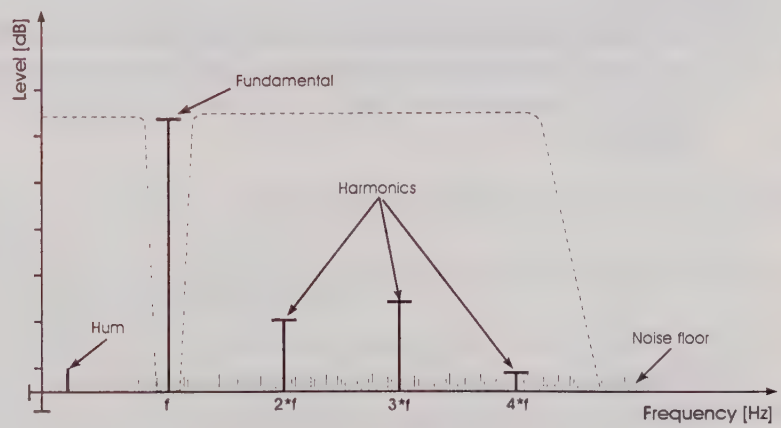

Fig 10 Conventional THD+N Acquisition

With a multitone test instrument, things are completely different. Here, the analyzer sums upall bins between each two signal bins, thus resulting in *n+1* distortion values (where *n* is the number of signal bins).

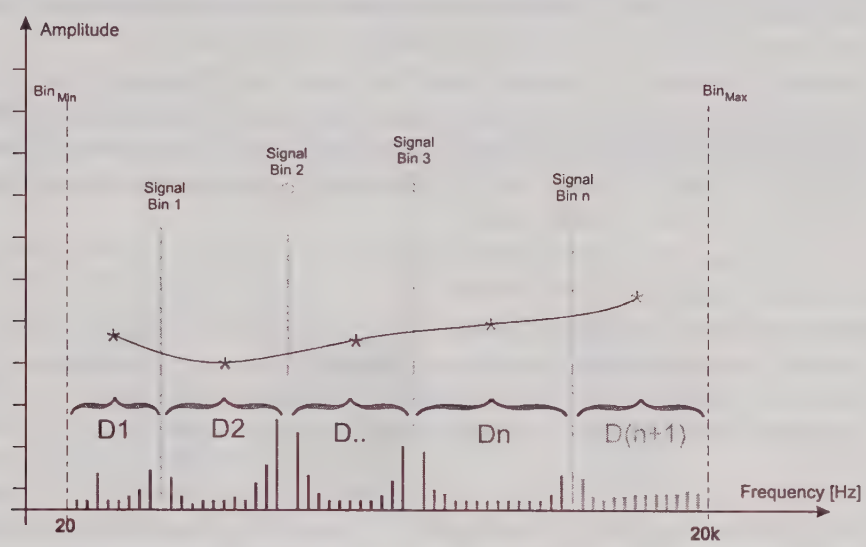

Fig 11 Multitone Distortion Acquisition

Consequently, these results may be called the TD+N values of the considered bands, i.e. the sum of all distortion plus noise.
Please notice the absence of the word 'harmonic' in this description. This is because of the numerous intermodulation products, that make the identification of the origin of any received signal component impossible.

THD+N Measurement

Sometimes, the operator of RAPID-TEST has to prove for a new application, that the THD+N (Total Harmonic Distortion + Noise) value of a DUT is the same, regardless if measured with a conventional test system or with RAPID-TEST. In order to provide the required result for such a comparison, the subsequent steps have to be executed.

1. Select a single test frequency f_{test} with which you want to stimulate the DUT.
2. Transmit a single-bin RAPID-TEST signal with this frequency and get the distortion result.
3. Calculate the THD+N result with the subsequent formula

$$THD+N\,[\%] = \frac{\sqrt{D_1[V]^2 + D_2[V]^2}}{\sqrt{D_1[V]^2 + L_1[V]^2 + D_2[V]^2}} * 100$$

with D_1 = distortion between 20Hz and the f_{test}, D_2 = distortion between f_{test} and 20kHz and L_1 = received level result.

The result of this procedure must be almost identical to the one of a conventionally acquired measurement. However, due to possible frequency shifts produced by the DUT, the values might differ slightly from each other.

Overview

- The THD+N measurement of the A2 uses a single sine tone as stimulus, and sums up all received signal components, except the fundamental one, over the complete frequency range.
- The RAPID-TEST instrument calculates the TD+N values for all frequency bands between the signal bins, by summing up all signal components in these bands.
- A direct relation between the distortion results of these two principles, in terms of a mathematical formula or similar, cannot be established. However, a DUT, that produces low distortion result when tested with RAPID-TEST, will as well show a very low THD+N value if conventionally tested.
- The smaller the number of signal bins is, the easier becomes a comparison between a multitone and a conventional measurement result.

Noise

The noise measurement is acquired almost identically to the distortion, however, with one major difference: its result is calculated by summing up the odd bins only in the respective frequency bands. But what does this mean? To give an answer, it is necessary to have a closer look on the FFT analysis which is performed on the incoming time signal.

As stated in chapter ***Bins & Signal Bins*** (p. *7*), the available frequencies of a multitone signal (bins), are given by the number of samples (blocklength) for one FFT. Therefore, one could expect that a multitone signal, which has been generated with a blocklength of 512, should be analyzed with the same blocklength as well. However, in practice the blocklength of the analyzer is twice as high as of the generated signal (1024 instead of 512), providing a twice as high frequency resolution of the resulting spectrum.

Since distortion products are always integer multiples of their fundamentals, they must always fall onto the *even* bins.
On the other hand, the received results from the *odd* bins must represent the noise, that was generated by the DUT itself.
This explains how to extract a noise value out of a received multitone signal.

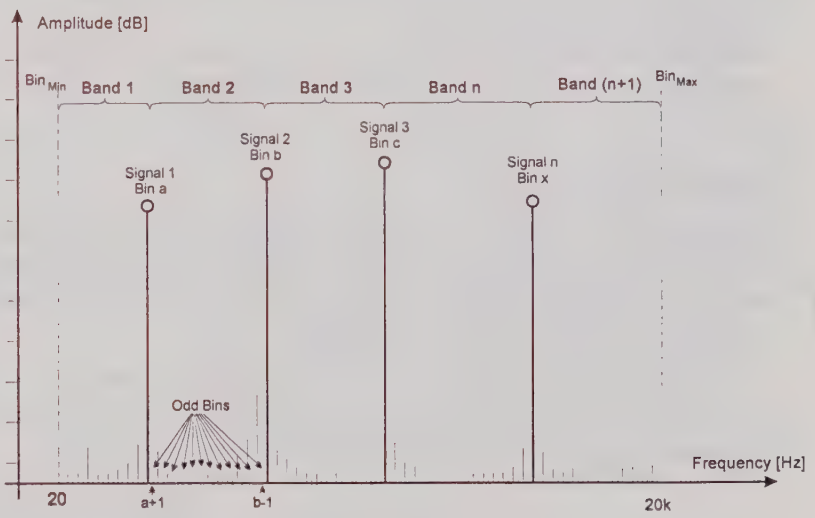

Fig 12 Multitone Noise Acquisition

Remains the question, how a conventional system measures noise. The answer is rather simple. According to the international standards, noise is measured by feeding the incoming signal through a special circuit, which transforms its low-energy peaks into a signal with detectable RMS value.

- Conventional noise analysis measures the quasi-peak Voltage of the incoming signal.
- The noise result of RAPID-TEST is acquired by summing up the odd bins of the analyzed signal.
- A direct relation between the results of these two principles, in terms of a mathematical formula or similar, cannot be established. However, under the assumption, that the noise of a*stimulated* DUT is measured, the results are qualitatively comparable

NOTE ***Please notice, that the multitone approach allows to measure Idle Noise, i.e. the noise being generated by the DUT in the presence of the test signal, while for a conventional noise measurement, the inputs of the DUT must be muted.***

Phase

Concerning the phase measurement, things are quite easy, since the conventional and the multitone method proceed in an almost identical way. In both cases, the phase difference between the two input channels is measured for each frequency.

The only difference concerns the recording of a complete phase response. With multitone testing, this may be acquired in one step, while with a single sine stimulus, the signal frequency has to be swept through the frequency band of interest. In any case, both methods provide the same results.

Crosstalk

The principle to characterize the crosstalk between two signal lines is almost identical in conventional as in multitone test instruments. The system transmits a signal through one channel only and calculates the ratio between this signal and the measured input signal of the alternate channel.

Both approaches provide the same results. However, there is a difference between the two methods, since RAPID-TEST can generate and analyze different signal bins on its two channels.
This allows the instrument to acquire the crosstalk results for both channels in parallel, by transmitting two multitone signals with different signal bins at a time, and to measure the crosstalk from ChA → ChB and ChB → ChA in one step only.

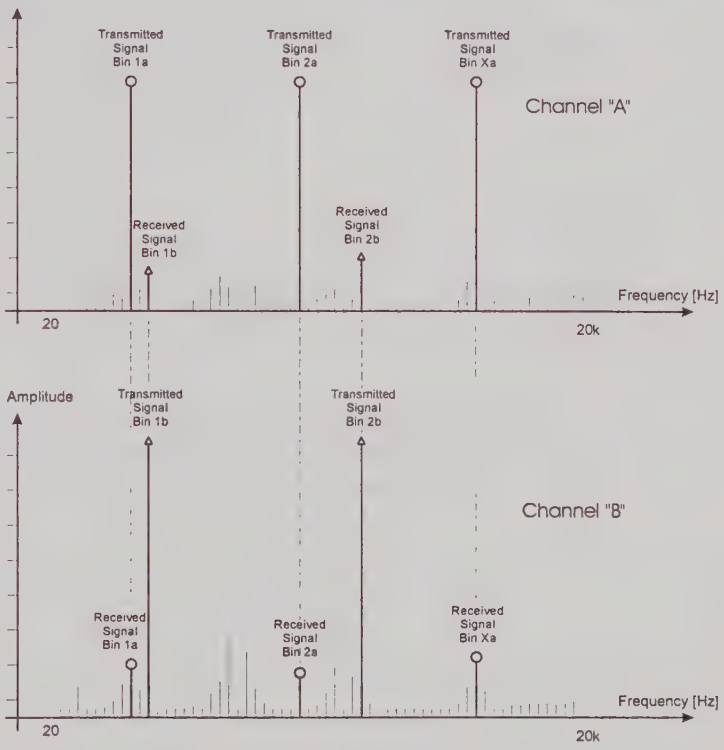

Fig 13 Multitone Crosstalk Acquisition

CONCLUSION

Comparability Overview

Table 2 provides a rough overview on how good the five measurement functions, investigated in this application note, can be compared if acquired with the conventional or multitone approach

	Conventional (single tone)	*Multitone*	*Comparability*
Level	broadband level or level selective	levels of received signal bins	**Good**
Distortion	THD+N of complete frequency range	TD+N of bands between signal bins	**Qualitatively only**
Noise	quasi-peak weighted noise	sum of odd bins between signal bins	**Poor**
Idle Noise	not possible	same as Noise	**-**
Phase	phase difference between input signals	phase differences at the received signal bins	**Good**
Crosstalk	crosstalk at generated signal frequency	crosstalk at signal bins	**Good**

Table 2 Comparability Overview

Summary

Both the conventional approach with single-tone stimulus and the multitone signals are equal methods to measure the five core audio parameter Level, Distortion, Noise, Phase and Crosstalk. As long as the respective backgrounds are known, the interpretation and comparison of the results is possible and easy.

The main advantage of multitone vs. conventional testing is the superior *speed* of the first method. Therefore, RAPID-TEST is the ideal choice for all applications where some core measurement functions shall be evaluated in a minimum of time.

Application Note

RAPID-TEST

Cellular Phone Testing

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ABSTRACT

Quality control (QC) of cellular phones usually comprises several stages, as e.g. hardware tests at PCB level, measurements of some audio parameters (frequency response, distortion or SINAD, S/N ratio etc.), ringer & DTMF tests or RF power recording. Since these tests typically have to be performed in production lines with high throughput, the core requirements for any test equipment are speed & accuracy as well as automated operation.

RAPID-TEST with its advanced multitone technique offers the analysis of up to six standard audio parameters in parallel within miliseconds onl. By this means, RAPID-TEST typically cuts audio test intervals down by a factor of up to 20 vs. conventional test instruments, still providing detailed results for QC or later statistical evaluation.

Communication with RAPID-TEST is very simple by using a controlling computer with installed IEEE-488.2 interface. This allows programming of individual applications, fitting exactly to the user's requirements.

Assumptions

This document was written for engineers who are interested to get details about cellular phone testing with RAPID-TEST. It is supposed that the reader provides a basic understanding of the subsequent topics.

- The meaning of the standard audio measurement functions such as frequency response, distortion (or SINAD), noise etc. and conventional measurement methods.
- Characteristics and typical applications of multitone signals.
- Writing software in a language like BASIC, LabView®, C, PASCAL etc. in order to remotely control an instrument through an IEEE parallel interface.

Required Equipment

On the hardware side, RAPID-TEST must be connected to the controlling PC through an IEEE-488.2 communication interface. NEUTRIK recommends to use one of following interface cards from NATIONAL INSTRUMENTS™, since this allows to use the evaluation software RT-EVAL, that is availble from NEUTRIK free of charge

- GPIB-PCMCIA
- GPIB-PCII/IIA (production year 1992 or later)
- GPIB/TNT

For integration into an automated environment, the necessary code may be written under any programming language providing I/O control commands for the available interface. Please refer also to application note ***Get Familiar with Writing Code for RT-1M*** and the code generation feature of the NEUTRIK evaluation software package RT_EVAL.

BASICS

The core purpose of a cellular phone - like of any other radio communications equipment - is the transmission of human voice information from one phone through the subscriber to another phone. Therefore, one of the most important buying criteria for cellular phones is their sound transmission quality - a characteristic depending on several elements.

Regardless of the used phone type, the electroacoustical transducers are microphones on the transmitter side and earpieces (i.e. miniature speakers) on the receiver side. Additionally, many other components and modules are responsible for sound transmission and therefore directly influence the audio quality. Their testing shall be discussed in this article.

Internal Structures of Cellular Phones

Normally, analog cellular phones transmit the bandlimited, frequency modulated (FM) audio information via the RF carrier according to the NMT, TACS or AMPS standard. The network forwards the signal to the closest bearer station. The called phone receives the signal, demodulates it and presents the reconstructed audio information at its earpiece.

In practice, the output stage of an analog cellular phone (*Fig 1*) comprises an emphasis filter for bandwidth limitation. Consequently, the input stage must inhere the corresponding de-emphasis filter behind the demodulator.

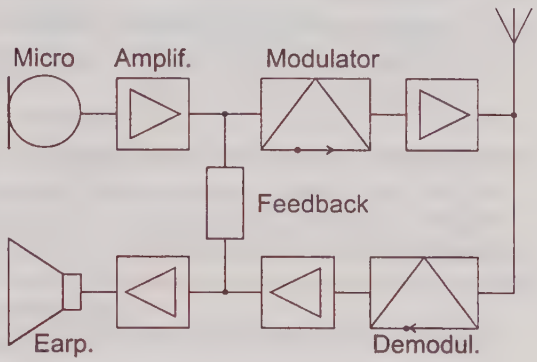

Fig 1 Block Diagram of Analog Cellular Phone

In digital cellular phones - as in their analog counterparts - a microphone converts the incoming sound waves into an electrical signal which is bandlimited and filtered (*Fig 2*). After its analog-to-digital conversion, the resulting bit stream is PCM-encoded and modulated for transmission. However, in order to minimize the amount of data to be transferred, special data reduction techniques are applied on the digital bitstream before it is modulated. This means that redundancies or inaudible parts of the audio signal are removed by using frequency masking algorithms such as MPEG I-III. Finally, the digital data stream is transmitted via RF carrier using standard procedures such as TDMA, CDMA, QPSK, GSM or DCS1800.
Like in analog phones, the receiver path of digital cellular phones in principle corresponds to an inverted transmitter.

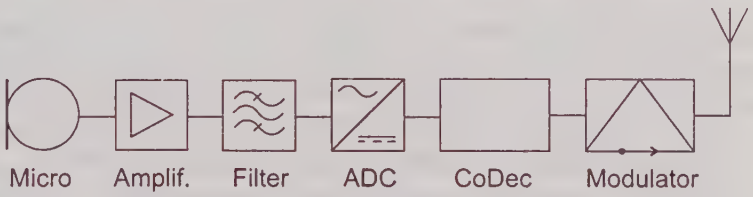

Fig 2 Block Diagram of Digital Phone Transmission

Regardless of the cellular phone type, the user-to-user connection can be considered as an analog-to-analog transmission with more or less signal processing in between. Hence, by measuring the standard audio parameter of a cellular phone as e.g. frequency response etc., the transmission characteristics of almost all directly involved modules and components may be evaluated.

Requirements for a Cellular Phone Test

Basically, when testing audio parameter of voice transmitting equipment, some core requirements have to be obeyed.

- ***High throughput***, i.e. a fast analysis of the selected audio parameter is a core requirement for production lines where hundreds of units have to be tested daily.
- ***Accurate and repetitive results*** are obviously vital for QC procedures, where the transmission characteristics of audio equipment have to be measured and PASS/FAIL decisions according to defined tolerances have to be taken.
- ***Close correlation to real world signals*** (i.e. human voice) with its typical mixture of different frequencies.
- ***Independent generation and analysis of the test signal(s)*** in order to enable either transmission tests or analysis of signals, that are generated internally by the phone.
- ***Automated remote control*** is a demand correlating closely with the production of large quantities of cellular phones or similar audio equipment, since it allows replacement of time- and cost-intensive manual procedures.

In the past, conventional techniques were used for these tasks, e.g. by measuring at few frequencies only or by sweeping a sine signal through the audio band of interest, thus obtaining the desired results. However, this approach suffers under several drawbacks, especially the long measurement duration.

Single Tone vs. Multitone Signal Testing

In contrast to a single sinusoidal tone, a multitone burst is a synthesized signal of short duration, containing several frequencies simultaneously. This approach offers numerous advantages.

- **Drastically reduced test time** by transmission of several frequencies simultaneously. The analysis of such a burst, lasting only few hundred milliseconds, results in frequency response, distortion (or SINAD) and noise values, acquired in one step only. This reduction of test time enhances the production density in a factory enormously, since audio testing usually is one of the most problematic bottlenecks in industrial environments.
- **Multifrequency test signals correspond much better to the real world** where human voice information, containing a lot of different frequencies, have to be processed and transmitted.

The only disadvantage of testing with a multitone stimulus is, that its results are not always directly comparable with a conventionally acquired result, and that it requires a certain understanding of the multitone technology before setting up a complete test system. Consequently, this application note explains these two topics in more detail.

Data Reduction Techniques and Multitone Testing

As mentioned above, digital cellular phones use data reduction algorithms in order to minimize the amount of data to be transmitted. This technique not only allows to omit all information which does not contribute to a proper understanding of the spoken words, but also increases the available network capacity in a given RF bandwidth.

The key parameter for any digital sound transmission is the necessary data rate, i.e. the number of bits to be transferred per second.

For instance, transmission of an uncompressed (i.e. not data reduced), digitized noise signal requires a data rate of

$$\text{DataRate} = \text{SamplingRate} * \text{CoderResolution} * \text{NumberOfChannels}$$

Equation 1 Required Data Rate

- According to the sampling theorem, the *sampling rate* has to be at least twice of the highest frequency occurring in the audio signal. Most applications with speech transmission, showing a maximum frequency of about 3kHz, are realized with a sampling rate of 8kHz.
- The *coder resolution* of the A/D conversion is always 8bit and determines the dynamic range, i.e. the signal-to-noise (S/N) ratio.
- The *number of channels* to be transmitted obviously increases the data rate proportionally.

For instance, by application of an 8bit coder (providing a maximum S/N ratio of 48dB), being driven by a 8kHz oscillator the resulting 1-channel data rate would be 64kbits/sec. However, as you may imagine, this value is not acceptable for ordinary voice transmission in a telephone network, since it would require an immense network capacity.
Therefore, modern telecom equipment use advanced techniques for data reduction in order to diminish the necessary data rate to about 8kbits/sec by eliminating transmission of redundant or not audible signal components.

Remains the question, what may be removed from the human voice audio signal without destroying its core information? The answer may be given after a short glimpse on psychoacoustics, i.e. the human hearing related effects which may be used for data reduction.

Masking Effects

In practice, the human ear shows a variety of changing sensitivities - called masking effects - of which the two most important ones depend on the applied noise level and presence of different frequencies in the signal. As a consequence, a human ear cannot always hear all signal components of the incoming noise. The origin of these masking effects is the traveling wave on the inner ear basilar membrane. A pure tone excites the basilar membrane not only at a certain place, but in a widespread area. Furthermore, the spectral envelope of the traveling wave is asymmetrical, with a steep slope towards lower frequencies and a shallow slope towards higher frequencies.

Level Masking

The frequency response of the human hearing system has its highest sensitivity in the frequency range between 2kHz and 4kHz, decreasing for higher and lower frequencies. Additionally, it depends strongly on the level of the incoming noise (***Fig 3***). The dotted curve represents the auditory threshold.

The complete set of curves, characterizing the sensitivity of the human ear at different frequencies, is called *level masking*.

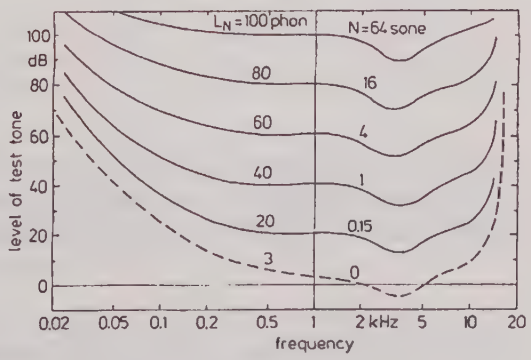

Fig 3 Sensitivity of the Ear

Spectral Masking

This term means that a certain tone may become inaudible if another signal with close frequency but higher level is present simultaneously. In this case, the high level tone masks other tones with similar frequency but lower level. *Spectral masking* can be characterized by complicated and nonlinear tuning curves of the human ear as e.g. shown in ***Fig 4***.

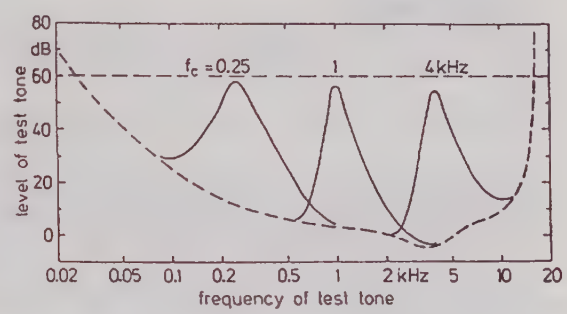

Fig 4 Spectral Masking Curves

For instance, an 1.5kHz sine tone with 20dB is clearly audible if no other signal is present. However, as soon as a 1kHz tone with 60dB is introduced, the first tone (1.5kHz) becomes inaudible.

Fortunately, this knowledge gives way to solve the data reduction problem. Obviously, any digital sound transmission has to transfer the audible tones only, while inaudible signals may be omitted according to the described characteristics without risking the loss of spoken information.

Conclusion

But what has all this to do with the core question, asking for the efficiency of a multitone analyzer technique, applied on a digitally coded and data reduced signal?

To answer this, lets assume that a certain phone under test would suffer under a high digital error rate. Obviously, this defect would result in a reduced amount of usable transmitted information and the phone would sound bad in practical use. However, when tested with a single sine tone only, a PASS may result, since the processing power of the phone can still be sufficient to reconstruct the single frequency, as long as no masking effects need to be calculated in the phone.

However, if the test is repeated with a multitone signal, the electronics of the phone not only would have to transmit more encoded information, but also to calculate simultaneously the masking effects for data reduction. As a consequence, the missing bits would cause an audible increase of the noise floor plus a drop of higher signal frequency levels.
This defect could be uncovered easily in the multitone receiver by analysis of the recorded audio parameter.

CELLULAR PHONE TESTING WITH RAPID-TEST

The goal of any cellular phone QC test procedure is not only to verify the given sound transmission specifications, but also to localize faulty components or uncover maladjusted circuits.
For these purposes, following tests emerged to be most commonly used.

- A ***PCB test*** electrically checks the characteristics of the assembled PCB.
- ***Transmit & Receive testing*** refers to the transmitting and receiving path of the cellular phone.
- ***Sidetone tests*** analyze the feedback path from the phone microphone to the earpiece.
- ***Ringer testing*** verifies the specified alarm sound of the cellular phone under test.
- ***DTMF tests*** measure the frequencies of the internally generated signals, corresponding to the pressed keys, and compare them vs. the respective standards.

Most production lines are designed for a certain order of tests, being located at different production stages. Fortunately, because virtually all of these tests measure the same specifications, it is possible to design a default test setup. This default environment may e.g. comprise a defined controlling PC, interface card, peripheral instruments like amplifier, RF-(de)modulator, microphone etc. and, most important, software modules.

Configuring RAPID-TEST

Typical measurement functions of cellular phone tests are level, distortion, noise floor and signal-to-noise (S/N) ratio at 3 to 4 different frequencies - all of them being measured in a single step only by using the advanced multitone technique of RAPID-TEST.

In practice, it is recommended to proceed as follows to configure the unit.

- Define the multitone signal.
- Set the output level.
- Adjust the input range.

These three steps usually have to be done once only during the initial installation of RAPID-TEST in the test stand. From then on, they are no more changed in order to get comparable results.

For a practical phone test, there two things remain to be done only.

- Send and receive the multitone burst.
- Measure the desired parameter.

Multitone Signal Definition

For easier understanding, it is best to describe the multitone signal definition process with a practical example. For this reason, it is assumed that a multitone signal comprising 4 signal bins has to be defined. The frequencies shall be identical on both channels, with values of 300Hz, 1.2kHz, 2.1kHz and 3.0kHz, which is a typical choice for telecom applications.

NOTE	**In this document, the frequencies and phases, which form a multitone signal are called *signal bins*.**

The subsequent example is restricted to a minimum of signal definitions only. If additional definitions are necessary (e.g. set outputs floating etc.), please refer to *RT-1M User Manual*.
The basic command, which has to be used to define a signal and to store it in RAPID-TEST, is

```
OUTPUT:MTONE:PARAMETER ...
```

It requires definition of the subsequent 9 parameters in the indicated order.

- ***Signal Number***. This parameter is a number from 1 to 4, indicating the target memory of the multitone signal in RAPID-TEST.
- ***Signal Name*** is an ASCII string of up to 8 characters, identifying the signal individually.
- ***Number of Samples***. This parameter - also called *blocklength* - must be chosen out of 5 available values (512, 1024, 2048, 4096 or 8192).
- ***Number of Signal Bins for Channel 1*** indicates the number of signal bins in channel 1.
- ***Number of Signal Bins for Channel 2*** indicates the number of signal bins in channel 2 (does not need to be identical with channel 1).
- ***Signal Bin Number(s) Channel 1***. Integer(s), defining the signal bins, i.e. the frequencies of channel 1 (please notice that as many bin-numbers have to be defined as indicated by parameter *Number of Signal Bins for Channel 1*).
- ***Signal Bin Number(s) Channel 2***. Integer(s), defining the signal bins, i.e. the frequencies of channel 2 (please notice that as many bin-numbers have to be defined as indicated by parameter *Number of Signal Bins for Channel 2*).
- ***Phase(s) of Channel 1 Bins*** sets the phase shifts for each signal bin for channel 1.
- ***Phase(s) of Channel 2 Bins*** sets the phase shifts for each signal bin for channel 2.

The subsequent paragraphs explain the most important of these multitone signal parameter and contain hints on their optimal definition in cellular phone tests. Further details are filed in application note *Get Familiar with Writing Code for RT-1M*.

Number of Samples / Blocklength

The number of samples - or *blocklength* - indicates with how many samples the multitone signal shall be represented in the time domain. The user must select one out of five available values, 512, 1024, 2048, 4096 and 8192. A high blocklength results in a long signal duration, however, it also provides a larger number of available signal bins.

Number of Signal Bins for Channel 1 / 2

The two independent values indicate how many signal bins are set for channel 1 and channel 2. Although normal cellular phone tests require few (3 to 5) signal bins only, it may be necessary to increase this number drastically in order to evaluate the influence of data reduction algorithms.

Signal Bin Number(s) Channel 1 / 2

Each signal bin must be identified by a number, indicating its frequency. For its calculation, one first has to evaluate the *frequency resolution* Δf according to

$$\Delta f = \frac{48000\,Hz}{Blocklength}$$

Equation 2 Frequency Resolution

To get the *Signal Bin Number*, one simply has to divide the desired signal bin frequency by Δf. In our example, lets assume a blocklength of 4096, resulting in a frequency resolution of Δf = 11.7Hz. Consequently, 300Hz equals the signal bin number 26 (300 ÷ 11.7 = 26), 1.2kHz equals 102, 2.1kHz equals 179 and 3.0kHz equals 256.
Please notice, that the actual frequencies of the signal bins are not always exactly identical with the desired values (for instance, signal bin number 26 corresponds to a frequency of 304.7Hz and not, as desired, exactly 300Hz). Fortunately, the resulting differences have no impact on the measurement accuracy, and are usually acceptable. However, if a more precise correspondence is vital, the blocklength may be increased to get a better frequency resolution.

Phases of Signal Bins

The *phases* of the signal bins exert a direct influence on the shape of the multitone signal, usually characterized by the Crest factor c_f. The better the phases are chosen, the smaller is the Crest factor and the required dynamic range of the DUT. Please refer to *RT-1M User Manual* or application ***note Get Familiar with Writing Code for RT-1M*** for further details.
In practice, it proved to be sufficient to assign random phases to the signal bins, i.e. in most cases it is not necessary to optimize the phases with the aid of complicated approaches.

Complete Command

With this knowledge, it becomes possible to write down the complete command defining the multitone signal of our example.

```
OUTPUT:MTONE:PAR 1,"4_Tone",4096,4,4,26,102,179,256,26,102,179,256,
  -2.488839,0.118530,-1.416581,2.392723,-2.488839,0.118530,-1.416581,
  2.392723
```

This command has to be sent to RAPID-TEST, where it is stored in the indicated memory location #1 and immediately ready for transmission. However, before starting the transmission, it may be necessary to adjust some further optional settings.

- The *front* or *rear* input connectors of RAPID-TEST may be identified and set to either *float* or *ground mode* (balanced / unbalanced operation)
- The *SYNC mode* defines how the analyzer synchronizes itself to the incoming signal.
- An additional *pretrigger-* and *multitonelength* may be introduced in order to challenge the effects of automatic gain controls (AGC) and transient responses in the DUT, or to improve the noise insensitivity of the multitone test.
- A proper *output level* is necessary to avoid overloading of the DUT.
- The *input range* of RAPID-TEST has to provide enough headroom towards the expected input signal level.

Input Connection

After the physical installation of RAPID-TEST into any test stand, one has to tell the controller of the unit whether it is connected through its front or rear panel with command

```
INPUT:FRONT [ON|OFF]
```

Furthermore, the user must decide whether the generator outputs shall be floating (i.e. electrically isolated) or grounded with command

```
OUTPUT:FLOAT [ON|OFF]
```

SYNC Mode

This parameter defines, in which way the receiving analyzer shall synchronize itself to the incoming multitone burst. It can be set by sending following instruction to RAPID-TEST

```
INPUT:SYNC:[INT|INTN|EXT]
```

INT

internally connects the analyzer with the sampling clock of the generator. The transmitted burst is sampled with exactly this clock rate and comprises a header. No frequency shifts must occur on the signal path. Signal analysis starts upon recognition of the trigger in the transmitted burst.
Recommended mode for almost noise-free environments.

INTN

also internally connects analyzer and generator of the unit. However, the multitone burst comprises no header and must be transmitted within 50ms from the generator to the analyzer of the same RT-1M unit. This mode allows the analysis of signals in very noisy environments, that make the header unrecognizable. No frequency shifts must occur on the signal path.
Recommended mode for typical industrial environments with high surround noise or analysis of externally generated signals (e.g. ringer test).

NOTE	**If an externally generated signal shall be analyzed, the analyzing unit must be triggered with command** `OUTPUT:MTONE:START` **to the incoming signal.** **In SYNC mode** `INTNoheader`**, the max. allowable delay of the transmitted signal on its path is 50ms, while the other two SYNC modes allow a delay of 1 sec.**

EXT

lets the analyzer synchronize itself to the 'Sync block' in the header of the incoming burst (i.e. not to the internal generator clock). Obviously, the burst to be analyzed must contain a header and hast to be sent off by a RAPID-TEST. However, the generator may be located remotely from the analyzer and frequency shifts or time delays up to 1 second are allowed.
Recommended mode for DUTs that cause a noticeable frequency shift.

Pretrigger / Multitone Length

Frequently, some devices of a test circuit show a transient behavior (e.g. RF de-/modulators with an AGC or noise fate etc.) that needs some time to adjust itself onto the incoming signal.
If this time exceeds ≈20msec, it becomes necessary to place a pretrigger in front the trigger of the multitone burst. This pretrigger should last for the time of the transient behaviour and may be set by following command, wherein the integer number <Length> indicates the *pretriggerlength* in [ms].

```
OUTPUT:MTONE:PRETRIGGER <Length>
```

Alternatively, it is also possible to prolong the burst at its end by increasing the *multitone length*. For instance, if the signal path comprises complex filters causing group delays or showing transient responses, it may be necessary to repeate the multitone signal several times with following command (<Length> indicates the *multitonelength* in [ms]) in order to allow stabilization of the incoming signal.

```
OUTPUT:MTONE:MTONELENGTH <Length>
```

Output Level

The *output level* of a multitone signal always is of vital interest, since it must fit into the dynamic range of the DUT. For cellular phone tests, there are two different ways to define this value.

On one hand, definition of the *RMS level* of the multitone burst may be required in cases where the energy content of the signal is the core characteristic. In this case, the *overall multitone signal RMS level* U_{mult}, i.e. the RMS level of all signal bins together, expressed in [V] or [dBV], may be set with following command (x = RMS level value, y = `V` or `dBV`).

```
OUTPUT1:LEVEL x y
```

Alternatively, it may be required to define a maximum *peak-level*, e.g. in order to avoid clipping. In this case, one may set the *overall multitone signal peak level* U_{mult} expressed in [Vp] or [dBVp], in order to limit the max. peak level of the complete multitone burst to a certain value. To do so, enter the subsequent instruction (x = peak level value, y = `Vp` or `dBVp`)

```
OUTPUT1:LEVEL x y
```

Practical Approach

A good approach to find an usable output level U_{mult} is to apply a single sine signal on the DUT and to increase its level until an overload occurs. At this point, measure the level, reduce it by the desired headroom (e.g. 3dB) and assume it as max. level U_{max} of the multitone signal.

If this measurement has been carried out with an instrument providing a result expressed in [dBm], please apply following formula to obtain [dBVp] which is acknowledged by RAPID-TEST.

$$U_{mult}[dBVp] = U_{\max}[dBm] + 0.79$$

Equation 3 [dBm] to [dBVp] Conversion

Input Range

The *input range* has to be set in a way that no overload of the RAPID-TEST analyzer occurs. The corresponding command, setting the input range e.g. to 0dBVp, is

```
INPUT:RANGE 0 dBVp
```

In practice, it is recommended to assume any input range and transmit a multitone burst. During transmission, watch the LED "Overload" on the front panel of RAPID-TEST.

1. If the Overload LED lights up, the input range has to be increased until the LED goes out.
2. If the Overload LED does not light up, the input range should be decreased stepwise until case 1 occurs. As soon as this happens, approx. +6dB should be added to the corresponding input range in order to assure enough headroom.

Alternatively, it is possible to calculate the expected bin levels of the received multitone signal. Under the assumption that the DUT has an almost flat frequency response, i.e. that the n received bin levels - herein called *return levels* U_{return} - are almost identical, they may be calculated according to

$$U_{return(expected)}[V] = \frac{U_{mult}[V] * A}{c_f * \sqrt{n}}$$ where A = gain of the DUT and c_f = Crest factor

Equation 4 Expected Return Level at Flat Frequency Response

To get the Crest factor of the transmitted multitone signal, simply use command

```
OUTPUT1:MTONE:CREST?
```

while the gain of the DUT must be known in advance.

NOTE	**Interpretation of the resulting data may be done only, if the values have been acquired with no errors, i.e. LED "Error" has not light up during the measurement sequence.**

PCB Test

Most types of cellular phones allow to bypass either the microphone or earpiece by direct electrical connection through an auxiliary contact, which is of special interest at an early stage of the whole QC procedure.
This electrical test, normally performed after assembly of the PCB, intentionally does not include an acoustical transmission. The reason is that an acoustical test obviously would not consider the influences of the housing of the phone, which at this stage is not yet assembled.

Transmit Test Setup

One of the most important QC procedures concerns the transmit characteristics of a cellular phone. For this test setup, RAPID-TEST is connected electrically to the phone under test as well as to a RF demodulator.

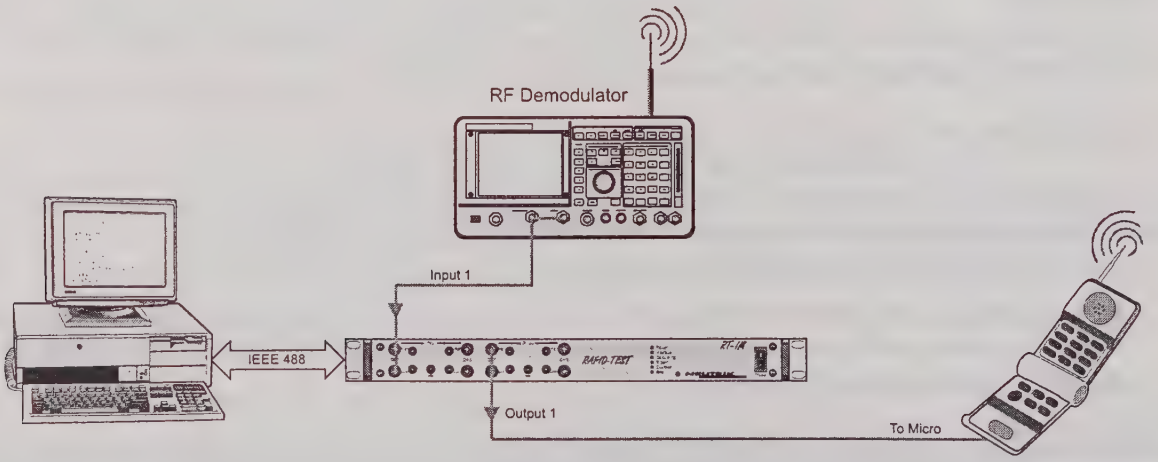

Fig 5 Transmit Test Setup

For Transmit testing, a multitone burst is introduced into the phone. It first passes the internal transmitter stages of the cellular phone, i.e. amplifier, filter, coder and RF modulator, before it is sent out by the antenna. Next, the multitone burst must be converted back to allow its analysis through RAPID-TEST. This conversion happens in an external RF demodulator, providing an electrical signal in the audio frequency range.

Receive Test Setup

On the other hand, evaluation of the receive characteristics of a cellular phone is at least as important. This time, RAPID-TEST must be connected electrically to the phone under test as well as to a RF modulator.

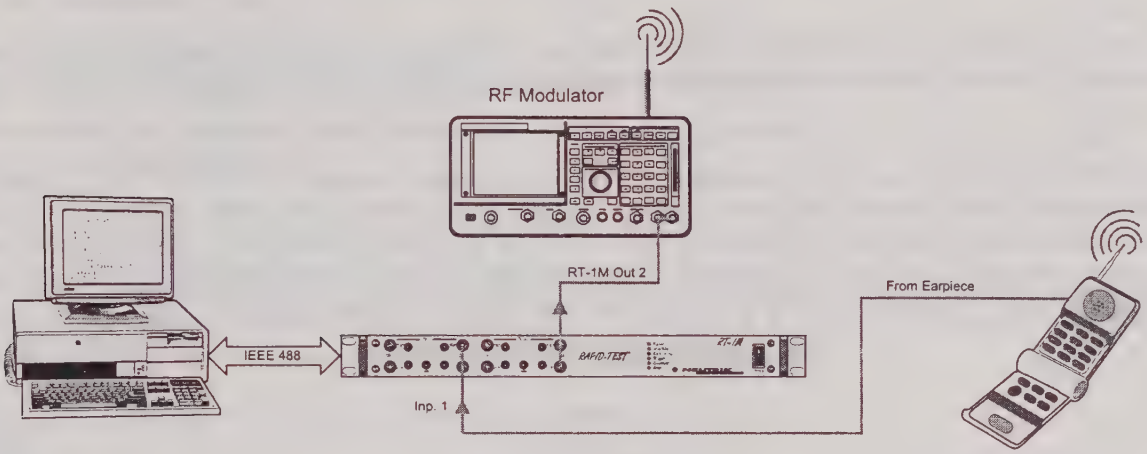

Fig 6 Receive Test Setup

For Receive testing the multitone burst must be RF modulated in an external modulator first, before it is received by the antenna of the cellular phone. The signal passes the internal receiver stages, wherein it is converted back into a signal in the audio range. Finally, it may be transmitted directly into RAPID-TEST for analysis.

In both cases (Transmit and Receive testing), a special firmware in the phone is required, allowing signal transmission without prior dialing. Finally, RAPID-TEST calculates the desired audio parameter from the received signal and to compare them against the predefined Pass/Fail criteria.

SLR and RLR

SLR (Send Loudness Rating) and RLR (Receive Loudness Rating), as defined by ITU-T Recommendation G.121 and the GSM 11.10 standard are measures of customer satisfaction of receive quality of a telephone call. Both parameter refer to the transmission loss between the phone microphone / speaker and an international switching point as shown below.

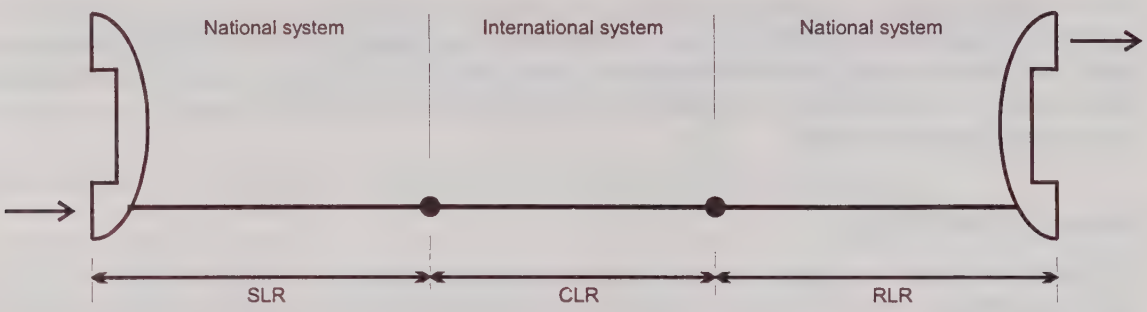

Fig 7 Loudness Rating Definition

Obviously, the SLR as well as RLR are closely connected to a Transmit / Receive test as described above. Therefore, they can be determined alternatively or additionally with a similar or even identical setup.

In practice, for SLR and RLR evaluation, one has to couple the amplified RAPID-TEST output signal through an artifical mouth[1] to the microphone of the cellular phone. The phone output level may then be measured by connecting its service output to the input of RAPID-TEST. On the other side, the phone earpiece has to be coupled with an artificial ear[1], which is connected to the alternate input of RAPID-TEST. Typically, a 1020Hz single sine tone is applied as test signal.

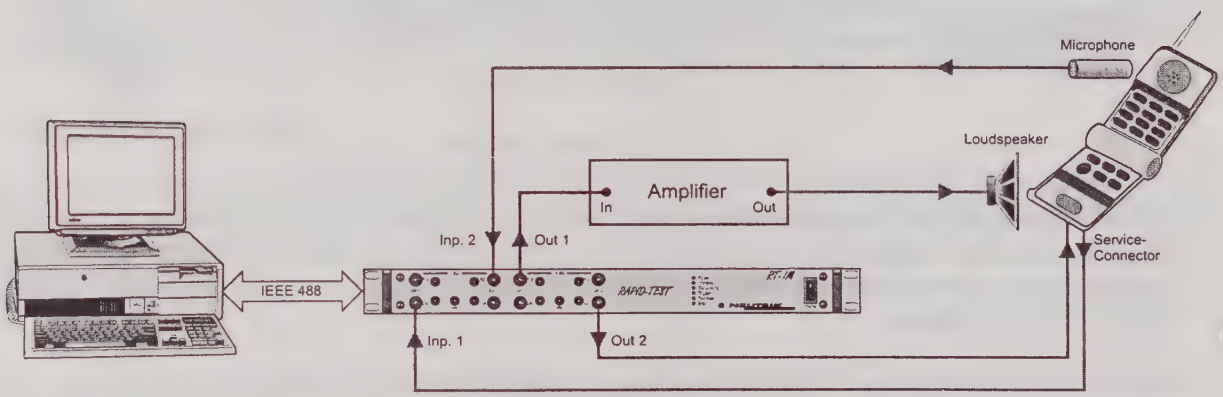

Fig 8 SLR & RLR Evaluation

By using this setup, the SLR and RLR may be calculated according to the subsequent formula.

$$SLR[dB] = 20 * \log(\frac{U_{Amp_Out}}{U_{RTIM_Inp1}}) \quad RLR[dB] = 20 * \log(\frac{U_{RTIM_Out2}}{U_{RTIM_Inp2}})$$

Equation 5 SLR & RLR Calculation

[1] An artifical ear & mouth consists of a calibrated microphone & loudspeaker with defined acoustical impedances, which are kept in a certain position, similar to the human model (see *ITU-T Recommendation P.64*).

Audio Parameter Measurements

Frequency Response

For calculation of the bandwidth, it is advisable first to define the highest of the measured return levels as reference $U_{ref}[V]$. Second, with linear interpolation between neighbored return levels, it becomes possible to check at which frequencies the level drops below a value of $U_{ref}[V]*0.707$ (see *Fig 9*). The two, thereby obtained frequencies set the 3dB bandwidth of the DUT.

All acquired results are stored in order to build a statistical database about good and bad phones. This allows to detect deviations from the nominal behavior.

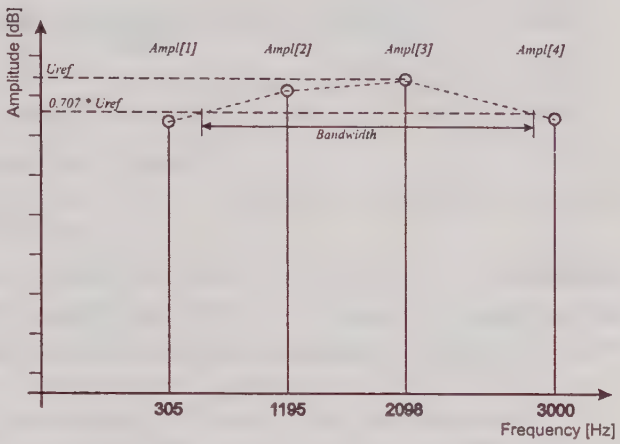

Fig 9 Level Plot

Total Input Value

For some evaluations as e.g. SINAD calculation, the *total input value*, equaling the root sum square (RSS) of the received signal - also called $U_{tot}[V]$ - is required. It can be calculated out of the *n* measured return levels $U_{return(n)}[V]$ (*n* also equals the number of signal bins).

$$U_{tot}[V] = \sqrt{\frac{\sum_{m=1}^{n} U^2_{return(m)}[V]}{n}}$$

Equation 6 Total Input Level Calculation

For instance, lets assume that the returned levels are -21dBV, -19dBV, -17dBV and -20dBV. First, these values have to be transferred from logarithmic into a linear unit.

$$U[V] = 10^{\frac{U[dBV]}{20}}$$

Equation 7 [dBV] to [V] Conversion

The resulting values are 89mV, 112mV, 141mV and 100mV. Applied on *Equation 6*, a total input value $U_{tot}[V]$ of 112mV results

$$U_{tot} = \sqrt{\frac{0.089^2 + 0.112^2 + 0.141^2 + 0.1^2}{4}} = 0.112[V]$$

NOTE	**Addition of the return levels for calculation of the total input level always has to be done with a linear unit. In case that the return values have been measured in dBV, convert them to a linear unit [V] first.**

Following BASIC sequence gives an example on how calculation of the total input level could be programmed. Make sure that the level is set to Volt.

```
1000 RMSLevel=0
1010 FOR I=1 TO 4 DO
1020    RMSLevel=RMSLevel+Ampl(I)*Ampl(I)
1030 NEXT I
1040 RMSLevel=SQRT(RMSLevel/4)
1050 Print "RMS Level is: ";RMSLevel
```

Program 1 Total Input Level Calculation

Distortion

As explained in chapter 1 of *RT-1M User Manual*, the calculated TD+N values (i.e. distortion) of a received multitone signal differ from conventional THD+N sweep results.

- Due to the simultaneous transmission of several frequencies in a multitone burst, *intermodulation* (IM) products are generated, which - together with the actual distortion - form the total distortion and noise (TD+N) value.
- In contrast to a continuous THD+N sweep the TD+N values equal the sum of the recorded levels in the band between two neighbored signal bins, while a THD+N sweep measures the RMS level of a bandpass-filtered input signal at certain frequencies.

Fig 10 shows a level plot of a received four tone signal, including all distortion and IM products between the signal bins. The TD+N value of each band may be calculated by summing up the respective distortion values excluding the signal bin levels, thus representing the total energy in the considered frequency range.

Obviously, for multitone signals with more than 1 signal bin, the result does not correspond directly to a conventionally measured THD+N value. However, both values are comparable in order to characterize a DUT. For instance, a DUT with a high THD+N value will show a high TD+N result as well and vice versa. This means, that you must not expect identical values from these two measurement modes, but that you will surely get reproducible and correct results, regardless of the selected method.

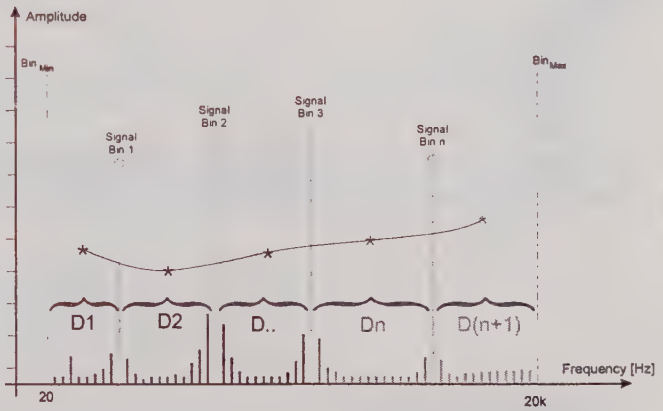

Fig 10 Distortion Plot

Please notice that application note *Get Familiar with Writing Code for RT-1M* provides a BASIC program (*Listing 5*) for query of distortion values.

NOTE	**The TD+N value, as calculated by RAPID-TEST, covers the distortion energy, intermodulation products and noise, generated by the multitone burst transmitted through the DUT. This result is similar but not identical to a conventional THD+N measurement, acquired by application of a single sine tone.**

SINAD

The SINAD value, which is widely spread in many applications, is defined as the overall RMS input signal level U_{tot}, divided by the sum of all distortions U_{Dist}.

$$SINAD[\%] = 100 * \frac{U_{tot}[V]}{U_{Dist}[V]} \quad \text{or} \quad SINAD[dB] = 20 * \log_{10}(\frac{U_{tot}[V]}{U_{Dist}[V]})$$

Equation 8 SINAD Calculation

Obviously, the SINAD value is directly correlated with the distortion of the DUT. Therefore, it becomes quite clear how to evaluate the SINAD value.

- Define a single or multitone signal with the desired frequencies, as for example
  `OUTPUT:MTONE:PAR 2,"SINAD",2048,1,1,26,26,0,0`
- Transmit this signal and record all return levels and distortion values from RAPID-TEST.
  ```
  MEASUREMENT1:LEVEL:UNIT V
  MEASUREMENT1:LEVEL?
  MEASUREMENT1:DISTORTION:UNIT V
  MEASUREMENT1:DISTORTION?
  ```
- Calculate U_{tot} by using U_{return} and *Equation 6*.
- Calculate *SINAD* by using U_{tot}, U_{Dist} and *Equation 8*.

Noise

Some QC standards require an noise measurement of a silent cellular phone. Obviously, such a test may be carried only out if the DUT is connected electrically to RAPID-TEST. Any acoustical coupling would result in unacceptably high requirements for an anechoic room.

Additionally, it is essential to obey following rules.

- Select SYNC mode `INTNoheader` and set the input range to maximum sensitivity.
- Mute the phone and start multitone signal transmission with command
  `OUTPUT:MTONE:START`
- Measurement of the noise value provides the desired results.

Sidetone Test

The sidetone test checks the feedback path between the cellular phone transmitter and its receiver (refer to *Fig 1*). This connection can be found in virtually every phone and is necessary to give the user the feeling that his unit is working properly.

The test itself evaluates the standard audio parameter of this path in order to allow comparison vs. specified tolerances. Coupling between RAPID-TEST and the phone may either be established using a speaker and a microphone, or - in case that the electroacoustical components of the cellular phone are tested at another stage - by direct electrical coupling via an auxiliary connector. Obviously, there is no demand for a RF (de)modulator since no signal transmission through the antenna occurs.

Anyway, the RAPID-TEST commands and queries, required for programming the unit are almost identical (except single parameter as e.g. input range etc.) to the Transmit & Receive test described above.

Measuring Phone-Specific Signals

Basically, there are two types of signals being generated internally in a cellular phone, the ringer sound and the double tone multiple frequency (DTMF) signals. The first is the well-known sound indicating reception of an incoming call, while the latter are the standardized tones corresponding to the dialed numbers.

Analysis of these two signal types requires an acoustical coupling between RAPID-TEST and the phone speaker generating the sound. For this purpose, it is necessary to obey two requirements.

- Connection of a precision measuring microphone to the input of RAPID-TEST (it is recommended to use the NEUTRIK 3382 microphone together with *RTiMPHAN* Phantom power supply).
- Tight acoustical coupling between the cellular phone speaker and the microphone.

The test itself may be done by taking full advantage of the distortion analysis mode of RAPID-TEST. If you watch once again the distortion plot as shown on page *Fig 10* of this application note, you will remember that RAPID-TEST measures all input levels between two signal bins and summarizes them to the TD+N value. This feature may be used to analyze any incoming signal with a specified frequency.

In practice, a multitone signal has to be defined, with one signal bin each being below and above the expected frequencies of an input signal. At this point, usually two questions arise.

- Why is it necessary to define an output signal for RAPID-TEST, although an externally generated signal shall be analyzed only?
- Why not set the signal bins to the same frequencies as of the ringer signal?

The answers are rather simple. First, multitone signal definition always applies on both the generator (sent-out signal bins) and the analyzer (expected frequencies of the incoming signal). Second, the phone signal generators usually are not exact enough to be relied on, and any mismatch between the expected and actual signal frequencies would cause faulty results.

Furthermore, it is important to know that RAPID-TEST must be enabled to recognize an externally generated signal by

```
INPUT:SYNC INTNoheader
```

This command states that the expected signal provides no header - as a RAPID-TEST multitone burst would do - and that the analyzer will be synchronized to the two frequencies, set by the well-known multitone definition command.

NOTE	**With SYNC Mode being set to `INTNoheader`, it is vital first to apply the external signal, before the analyzer of the unit is started by sending command `OUTPUT:MTONE:START`.**

Ringer Test

Normally, the ringer signal of cellular phone comprises 2 to 3 frequencies, which are sent out alternating and/or interrupted in order to attract maximum attention by the public (e.g. in a restaurant or elevator etc.). However, since this sound also serves as signature tune, the phone manufacturer may have a vital interest in its proper generation. Therefore, an adequate test must assure correctness of the specified melody.

Lets assume a ringer tone with two frequencies at 1.4kHz and 2.3kHz. To check, whether these two tones are generated correctly by the phone, one may take advantage of the RSS selective measurement function of RAPID-TEST. For this purpose it is necessary first to transmit a 'dummy' multitone signal, in order to let RAPID-TEST record the ringer signal. Next, the sampled signal may be used to calculate the levels of the two ringer frequencies.

- Define a 'dummy' multitone signal with a blocklength of 2048 and e.g. one signal bin at any frequency.
  `OUTPUT:MTONE:PAR 3,Ringer,2048,1,1,10,10,0,0`
- Connect Input 1 of RAPID-TEST with a microphone located near the phone ringer.
- Adjust the input range of RAPID-TEST to the proper value. For instance, if you don't know the expected input level, initiate constant ringing and decrease the input range of RAPID-TEST until you get an overflow error. Don't forget to add a certain headroom (e.g. +6dBVp).
  `INPUT:RANGE x dBVp`
- Set the synchronization mode of RAPID-TEST to Internal/NoHeader
  `INPUT:SYNC INTNOHEADER`
- Set the unit to
  `MEASUREMENT1:SELECTIVERSS:UNIT dBV`
- Activate the ringer of the phone and initiate RAPID-TEST to record the incoming signal
  `OUTPUT:MTONE:START`
- At the chosen blocklength of 2048, the two ringer frequencies correspond to the bin numbers 60 (1.4kHz) and 98 (2.3kHz). In order to check whether the recorded signal actually comprises these signal components, one may evaluate the RSS selective values in the two bands 1.35kHz-1.45kHz (bin numbers 58-62) and 2.25kHz-2.35kHz (bin numbers 96-100).
  ```
  MEASUREMENT1:SELECTIVERSS? 58 62
  MEASUREMENT1:SELECTIVERSS? 96 100
  ```

The results of this measurement correspond to the signal energies (i.e. amplitudes) in the two bands. Consequently, the operator may verify, whether

- the recorded level complies with the specifications *and*
- the frequencies of the ringer signal are within a tolerance of ~2%.

In a more advanced approach, one could also evaluate the RSS selective results *outside* these bands in order to check, whether unwanted distortion or noise signal components are generated by the ringer of the phone.

DTMF Signals

Similar to the ringer signal, DTMF (Double Tone Signal Frequency) signals are generated internally by the phone. They consist of 16 different frequency pairs, that indicate the dial keys 0-9, *, # and 4 more, user-defined codes as shown in *Table 1*.

	1209Hz	1336Hz	1477Hz	1633Hz
697Hz	1	2	3	*a*
770Hz	4	5	6	*b*
852Hz	7	8	9	*c*
941Hz	*	0	#	*d*

Table 1 DTMF Signal Coding

To obtain a frequency pair corresponding to a certain phone key, one simply has to look on top of the respective column and at the left side of the respective row. For instance, key *8* is coded by the DTMF signal with *852Hz* & *1336Hz*. The 4 fields *a-d* in the right hand column are reserved for special key coding.

RAPID-TEST provides an unique way to test this standard feature of every analog or digital phone in parallel to the analysis of its audio transmission quality. In order to start monitoring the input channel(s) on incoming DTMF signals, all the user has to do is to use the following command.

```
MEASUREMENT[1|2]:DTMF:START
```

Please notice, that RT-2X provides the possibility to monitor both input channels (1 and 2), while RT-1M with installed DTMF option may activate channel 1 only. From time to time, the received DTMF signals may be queried with command

```
MEASUREMENT[1|2]:DTMF?
```

Furthermore - with RT-2X only - it is possible to generate DTMF signals of different duration either at the specified frequencies or with a frequency deviation of ±10% and with selectable amplitude ratio between the two signal components. For this purpose, use command

```
OUTPUT:MTONE:DTMF <x>,<y>,<t>,<LoDev>,<HiDev>,<AmpRate>
```

and refer to the respective *RAPID-TEST User Manual* for further details.

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